Science Olympiad Codebusters

Guide for Coaches, Event Supervisors and Students

John Toebes
codebusters@toebes.com

Updated for the 2024-2025 season.

Disclaimer:
The official rules released on the Science Olympiad website are the official rules and used for all competitions. In the case of a difference, those rules and any FAQ clarifications override anything in this document.

1. Goals

Kids are fascinated by secret writing and more importantly excited by breaking those codes. The process of breaking the codes involves complex pattern matching and teaches kids skills which are critical to software development and science in general.

- Seeing patterns
- Frequency Analysis
- Quick guessing and trusting instinct
- Backtracking to correct errors

More importantly the process of solving ciphers in a fun style gets the kids addicted to ciphers in general.

2. Overview of Cipher Usages

Cipher map per year based on experiences from previous years for Divisions B/C.

		18-19	19-20		20-21		21-22		22-23		23-24		23-24	
Cipher	**Type**		**Reg.**	**State Nat**	**Reg.**	**State Nat**	**Reg.**	**Reg.**	**Reg.**	**State Nat**	**Reg.**	**State Nat**		
Dancing Men	Monoalphabetic Symbol	D												
AtBash	Monoalphabetic		ED		ED		ED		ED		ED		ED	
RSA	Numeric Math			IM										
Running Key	Polyalphabetic			ED										
Caesar	Monoalphabetic	D	ED		D		D		D		D		D	
Aristocrat	Monoalphabetic	DC	DC		DC		DC		DC		DC		DC	
Aristocrat Misspelled	Monoalphabetic	DC	DC		DC		DC		DC		DC		DC	
Patristocrat	Monoalphabetic	DC	DC		DC		DC		DC		DC		DC	
Xenocrypt	Monoalphabetic Language	DC (0 or 1)	DC (0 or 1)	DC (1+)	DC (0 or 1)	DC (1+)	DC (0 or 1)	DC (2+)	DC (0 or 1)	DC (2 +)	DC (0 or 1)	DC (2 +)	DC (0 or 1)	DC (2 +)
Hill 2x2	Polyalphabetic Math	EDM		EDM		EDM	EDM		EDM		EDM		EDM	
Hill 3x3	Polyalphabetic Math	DM		EDM		EDM		EDM		EDM		EDM		EDM
Affine	Monoalphabetic Math	EDC	ED	EDC	ED	EDC	ED	EDC	ED	EDC	ED	EDC	ED	EDC
Vigenère	Polyalphabetic	ED	ED	EDC	ED	EDC	ED	EDC						
Baconian	Steganography		C		C		C		C		C		C	
Morbit	Tomogrammic				D	DC	D	DC		DC				
Pollux	Tomogrammic				D	DC	D	DC		DC				

Fractionated Morse	Tomogrammic						D		D		D		
Porta	Polyalphabetic				D	D	D	D	D	D	D	D	
Railfence	Transposition				DC		DC						
Nihilist	Polybius Square								ED	EDC	ED	EDC	
Cryptarithm	Math						DM		DM		DM		
Complete Columnar	Transposition								C		C		

Key:

D – Decode (Cipher Text given with or without a hint)

E – Encode (Plain Text given with an encoding key)

C – Cryptanalysis (Cipher Text given with some corresponding Plain Text)

M – Mathematical computation

I – Identification of components

– Division B Only

– Not used

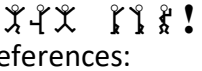
2.a. Division A Ciphers

Cipher	Type	2022-2023	2022-2023	2024-2025
Pigpen/Masonic	Monoalphabetic Symbol	D	D	D
Tap Code	Monoalphabetic	D	D	D
Running Men	Monoalphabetic Symbol		D	D
Vigenère	Polyalphabetic	ED	D	D
AtBash	Monoalphabetic	ED	D	D
Caesar	Monoalphabetic	D	D	D
Aristocrat	Monoalphabetic	DC	DC	DC

3. Cipher Descriptions

3.a. Running Men [Monoalphabetic Symbol] Div A

A symbol-based cipher associated with a Sherlock Holmes book – *The Adventure of the Dancing Men* written by Sir Arthur Conan Doyle. If a student memorizes the symbols, this can be easily sight-read. We include an unlabeled set of the symbols in the reference guide of the test.



References:

- https://en.wikipedia.org/wiki/The_Adventure_of_the_Dancing_Men
- https://www.dcode.fr/dancing-men-cipher
- https://www.omniglot.com/conscripts/dancingmen.htm
- https://twitter.com/NCSO_cb/status/846766212407345152

3.b. PigPen/Masonic [Monoalphabetic Symbol] Div A

The PigPen cipher is believed to have originated with the Hebrew Rabbis, but its biggest claim to fame is that it was used by the Knights Templar during the Christian Crusades. It was also heavily used by the Freemasons for keeping their records. As a result, it is also known as the Masonic or Freemason's cipher. This is a trivial cipher for students to encode or decode and the table is easily constructed from a couple of tic-tac-toe grids and Xs.

References:

- https://en.wikipedia.org/wiki/Pigpen_cipher
- https://www.dcode.fr/pigpen-cipher
- https://derekbruff.org/blogs/fywscrypto/historical-crypto/prying-open-the-pigpen-cipher/
- http://www.civilwarsignals.org/cipher/pigpencipher.html

3.c. Tap Code [Monoalphabetic] Div A

Also known as a knock code, the Tap Code Cipher was commonly used by prisoners of war in order to communicate with one another using pairs of up to 5 knocks to select a character from a 5x5 alphabet block (both C and K share the same spot). It only requires memorizing the letters AFLQV and then counting the knocks in the first set to advance along them and then count the knocks in the second set to figure out how much to advance the letter.

References:

- https://en.wikipedia.org/wiki/Tap_code
- https://www.dcode.fr/tap-cipher
- https://www.boxentriq.com/code-breaking/tap-code
- https://www.braingle.com/brainteasers/codes/tapcode.php

3.d. AtBash [Monoalphabetic] Div A Div B

An alphabet-based cipher originally used to encrypt the Hebrew Alphabet. It is easily adapted to other alphabets as it is simply all the letters reversed. This is a trivial cipher for students to encode or decode. One interesting property of this cipher is that by encoding text twice produces the original text. The AtBash cipher is used for Geocaching.

References:

- https://en.wikipedia.org/wiki/Atbash
- https://www.dcode.fr/atbash-mirror-cipher
- http://practicalcryptography.com/ciphers/atbash-cipher-cipher/
- http://rumkin.com/tools/cipher/atbash.php

3.e. RSA [Numeric math] (NO LONGER USED IN CODEBUSTERS -- MOVED TO CYBER SECURITY)

Algorithm used by modern computers to encrypt and decrypt messages. Relies on a private key for security and is based on finding factors of large composite numbers. Because the real algorithm requires numbers which cannot be computed on a calculator, we must do a very simplified one using two to four-digit primes. As such we can only have students find a single number and not text but are considering a simple chunking of a few characters.

References:

- https://en.wikipedia.org/wiki/RSA_(cryptosystem)
- https://simple.wikipedia.org/wiki/RSA_algorithm
- https://www.dcode.fr/rsa-cipher

3.f. Caesar [Monoalphabetic] Div A Div B

One of the earliest known and simplest cipher. Originally attributed to Caesar for his private correspondence. The ROT13 version (with a shift of 13) is in common use for computer software and online forums as a means of hiding spoilers. ROT13 is a reversable cipher such that applying it twice results in the original text (like the AtBash cipher). The Caesar cipher is also the basis for the Vigenère and Running Key ciphers. Both ROT13 and the general Caesar cipher are used for Geocaching.

References:

- https://en.wikipedia.org/wiki/Caesar_cipher
- https://youngtyros.com/2018/06/04/caesar-cipher/
- https://en.wikipedia.org/wiki/ROT13
- http://practicalcryptography.com/ciphers/caesar-cipher/
- https://www.dcode.fr/caesar-cipher
- https://www.dcode.fr/rot-13-cipher
- https://learncryptography.com/classical-encryption/caesar-cipher

3.g. Aristocrat [Monoalphabetic] Div A Div B Div C

Most commonly seen in newspapers as Cryptoquotes, an Aristocrat is the standard substitution cipher with the restriction that no letter maps to itself. This mapping of the alphabet can be random or in order to simplify the solving, could use a K1 (keyword in the plaintext alphabet), K2 (keyword in the Ciphertext alphabet), K3 (Keyword in alphabet, but plaintext/ciphertext is shifted) or K4 (different keywords in the plaintext and ciphertext alphabets).

References:

- https://en.wikibooks.org/wiki/Cryptography/Substitution_cipher
- https://youngtyros.com/2018/06/04/aristocrat-substitution-cipher/
- https://entertainment.howstuffworks.com/puzzles/cryptoquote-puzzles.htm
- https://cryptograms.puzzlebaron.com/tutorial.php
- http://rossinglish.blogspot.com/p/aristocrat.html
- https://toebes.com/Ciphers/Solving%20a%20K1%20Alphabet.htm
- http://www.cryptogram.org/resources/samples/Solving%20Sample%20A-1.pdf

3.h. Aristocrat Misspelled [Monoalphabetic] Div B Div C

Using the same mechanism, the words can be misspelled, or homonyms substituted. This increases the difficulty.

References:

- (See the Aristocrat section)

3.i. Patristocrat [Monoalphabetic] Div B Div C

The same rules as for Aristocrats applies here except that all spaces and punctuation is removed and only the letters are kept, separating them into groups for convenience. The most common grouping is 5 and has been adopted by the ACA as a standard.

References:

- https://youngtyros.com/2023/02/12/patristocrat-cipher/
- https://sites.google.com/site/bionspot/aristocrat-patristocrat-page
- https://codepenguincom.wordpress.com/tag/patristocrat/

3.j. Xenocrypt [Monoalphabetic Language] Div B Div C

Identical to Aristocrats, except the language of the plaintext is other than English. Although it is one of the lower attempted items, it often ends up being a differentiator and serves to bring in additional people with different skills to the team.

References:

- https://toebes.com/Ciphers/Samples/Code Busters 2018 Sample 9 Xenocrypt Solution.pdf
- https://youngtyros.com/2023/02/14/xenocrypts/

3.k. Hill 2x2 [Polyalphabetic math] Div C

The Hill cipher was invented by Lester S. Hill in 1929 which is based on linear algebra. It requires basic knowledge of matrix math to encode or decode. Given the encoding matrix, it is possible to determine the decryption matrix for a 2x2 Hill cipher. The process of encoding and decoding uses identical math taking the numeric equivalent of letters two at a time. This has an appeal to the math-oriented students.

References:

- https://en.wikipedia.org/wiki/Hill_cipher
- https://youngtyros.com/2023/02/19/affine-hill-cipher-types/
- http://practicalcryptography.com/ciphers/hill-cipher/
- https://www.geeksforgeeks.org/hill-cipher/
- https://crypto.interactive-maths.com/hill-cipher.html
- https://www.dcode.fr/hill-cipher
- https://massey.limfinity.com/207/hillcipher.pdf

3.l. Hill 3x3 [Polyalphabetic math] Div C

The 3x3 version of the Hill cipher uses the numeric equivalent of letters as triplets. The process of encoding and decoded is also identical to the 2x2 version. However, for a 3x3 the math for determining the decryption matrix from the encoding matrix is significantly more complex and probably beyond what we would expect to use at the event, so we provide the decryption matrix for decoding 3x3.

References:

- (See the Hill 2x2 references)
- https://www.dcode.fr/hill-cipher

3.m. Affine [Monoalphabetic math] Div B

The Affine cipher is a monoalphabetic substitution cipher where the mapping of letters is controlled by a function $(\mathrm{ax} + \mathrm{b}) \bmod \mathrm{m}$ where a

and b are the keys of the cipher and m is the size of the alphabet. Typically, we use m=26 in order to overlap with the tables used for the Hill ciphers, but a value of 27 (with space for 27) leads to more interesting math. If $a = 1$ then the Affine becomes a Caesar cipher with b indicating the shift value. If $a = 25$ and $b = 25$ then the Affine produces the AtBash cipher. The Affine cipher is used for Geocaching.

References:

- https://en.wikipedia.org/wiki/Affine_cipher
- https://youngtyros.com/2023/02/19/affine-hill-cipher-types/
- http://practicalcryptography.com/ciphers/affine-cipher/
- https://crypto.interactive-maths.com/affine-cipher.html
- https://www.dcode.fr/affine-cipher
- https://www.geeksforgeeks.org/implementation-affine-cipher/

3.n. Vigenère [Polyalphabetic] (Also known as the autokey cipher)

Div A

The Vigenère cipher is basically a collection of Caesar ciphers based on the letters of a repeated keyword. It was invented in 1553 and resisted all attempts to break it until 1863. It was also used during the American Civil War. The Vigenère cipher is used for Geocaching.

References:

- https://en.wikipedia.org/wiki/Vigenère_cipher
- https://youngtyros.com/2023/02/19/vigenere-cipher-type/
- https://www.geeksforgeeks.org/vigenere-cipher/
- http://crypto.interactive-maths.com/vigenegravere-cipher.html
- https://cryptii.com/pipes/vigenere-cipher
- https://www.dcode.fr/vigenere-cipher
- https://en.wikipedia.org/wiki/Autokey_cipher
- http://practicalcryptography.com/ciphers/autokey-cipher/

3.o. Porta [Polyalphabetic]

Div B Div C

The Porta cipher is a predecessor to the Vigenère cipher with only thirteen possibilities. It was invented by Giovanni Battista della Porta in 1563 and has the distinction of being the first cipher ever devised using a variable literal key.

References:

- https://en.wikipedia.org/wiki/Giovan_Battista_Bellaso
- https://youngtyros.com/2023/02/19/porta-cipher/
- https://www.cryptogram.org/downloads/aca.info/ciphers/Porta.pdf
- http://practicalcryptography.com/ciphers/porta-cipher/
- https://toebes.com/Flynns/Flynns-19260220.htm
- https://www.historyofinforMion.com/detail.php?entryid=3137
- https://www.dcode.fr/porta-cipher

3.p. Running Key [Polyalphabetic] NOT CURRENTLY USED

The Running Key cipher can be simply described as a version of Vigenère cipher except that the key is longer than the cipher. Typically, the plain

text is encrypted against a well-known book starting at an agreed upon passage. It is considerably more secure than the Vigenère cipher but can still be cracked. It doesn't appear to have any modern-day usage.

References:

- https://en.wikipedia.org/wiki/Running_key_cipher
- http://practicalcryptography.com/ciphers/running-key-cipher/
- https://www.aclweb.org/anthology/P12-2016
- https://crypto.interactive-maths.com/other-examples.html
- http://www.crypto-it.net/eng/simple/running-key.html?tab=0

3.q. Baconian [Steganography] Div B Div C

Initially devised by Francis Bacon in 1605, it is unlike the other ciphers in that it works to conceal the message in the text presentation rather than the content. There are many representations including alternate visual representations (i.e., bold characters), sets of symbols, and the word Baconian which look like headlines. The Baconian cipher is used for Geocaching.

References:

- https://en.wikipedia.org/wiki/Bacon's_cipher
- https://youngtyros.com/2023/02/13/baconian-cipher/
- http://rumkin.com/tools/cipher/baconian.php
- https://mothereff.in/bacon
- http://practicalcryptography.com/ciphers/baconian-cipher/
- https://www.geeksforgeeks.org/baconian-cipher/
- https://toebes.com/Flynns/Flynns-19250425.htm
- https://www.dcode.fr/bacon-cipher

3.r. Morbit [Tomogrammic] NOT CURRENTLY USED

The name nominally comes from **MOR**se **B**inary dig**IT** as a binary representation of Morse Code. Created by converting the plain text to Morse Code and then taking the Morse code pieces in pairs, encoding them at a single character. There are several variants, the most common being 9 digits which stand for all possible combinations of **–** **.** and space (typically represented by **X**). In general, because Morse code is longer than the equivalent characters, a Morbit encoded cipher text will be longer (approximately 50%) than the corresponding plain text. There are some theories that Kryptos (https://en.wikipedia.org/wiki/Kryptos) uses Morbit for the still undeciphered K4. The Morbit cipher is used for Geocaching.

References:

- http://www.cryptogram.org/downloads/aca.info/ciphers/Morbit.pdf
- https://youngtyros.com/2023/02/19/fractionated-ciphers/
- http://acaencodedecode.appspot.com/cipher_forms/morbit.html
- https://www.dcode.fr/morbit-cipher
- http://members.aon.at/cipherclerk/Doc/Morse.html
- https://web.itu.edu.tr/~orssi/dersler/cryptography/Chap2-1.pdf

3.s. Pollux [Tomogrammic] NOT CURRENTLY USED

The Pollux cipher is like the Morbit cipher, except that the Morse pieces are taken off a single digit at a time. Typically, more than one character is assigned to stand for **–** **.** and space (typically represented by **x**). Because of the Morse encoding, a Pollux encoded cipher text will be significantly longer than the corresponding plain text (approximately 2-3 times the size). The Pollux cipher is used for Geocaching.

References:

- http://www.cryptogram.org/downloads/aca.info/ciphers/Pollux.pdf
- https://youngtyros.com/2023/02/19/fractionated-ciphers/
- https://asecuritysite.com/coding/pollux
- https://sites.google.com/site/geocachinghelppuzzle/home/ciphers/appearance
- http://members.aon.at/cipherclerk/Doc/Morse.html
- https://www.dcode.fr/pollux-cipher

3.t. Fractionated Morse [Tomogrammic] Div B Div C

The Fractionated Morse is a combination of the Morbit/Pollux ciphers but using a K1/K2 type alphabet for the mapping where a single cipher letter stands for three Morse pieces. It was invented by ACA member FIDDLE in 1960. The letters in the keyword alphabet are mapped against a defined set of patterns with the first letter mapping to **...** and the last letter (very often the letter Z if it isn't in the keyword) mapping to **xx–**. Note that since there are only 26 letters in the alphabet, there is no mapping to **xxx**.

References:

- https://www.cryptogram.org/downloads/aca.info/ciphers/FractionatedMorse.pdf
- https://youngtyros.com/2023/02/19/fractionated-ciphers/
- http://practicalcryptography.com/ciphers/classical-era/fractionated-morse/
- https://www.dcode.fr/fractionated-morse
- https://sites.google.com/site/cryptocrackprogram/user-guide/cipher-types/substitution/fractionated-morse

3.u. Railfence [Transposition] (Also called a zigzag cipher) NOT CURRENTLY USED

The Railfence cipher works not by substituting letters, but by changing the order of the letters by putting them into a pattern and then reading them out in a different order.

References:

- https://www.cryptogram.org/downloads/aca.info/ciphers/Railfence.pdf
- https://youngtyros.com/2023/02/17/railfence-and-redefence-cipher/
- https://en.wikipedia.org/wiki/Rail_fence_cipher
- https://www.dcode.fr/rail-fence-cipher
- https://crypto.interactive-maths.com/rail-fence-cipher.html

- http://rumkin.com/tools/cipher/railfence.php

3.v. Cryptarithm [math] Div B Div C

Cryptarithms are a great cross between ciphers and mathematics. In them mathematical formulas with letters taking the place of their corresponding numbers are given to solve. The answer is driven from sorting the mappings of the letters. The actual origin of Cryptarithms is not quite known as they have been seen as far back as 1864. Although Cryptarithms can be done in any base, for Science Olympiad we will be sticking to Base 10 which means that any problem with have 10 unique letters.

References:

- https://en.wikipedia.org/wiki/Verbal_arithmetic
- https://youngtyros.com/2023/02/19/cryptarithms/
- https://www.futurelearn.com/info/courses/recreational-math/0/steps/43523
- https://nrich.maths.org/cryptarithms
- https://www.dcode.fr/cryptarithm-solver
- http://www.arml2.com/arml_2017/public_power_contest/contest_archive/Fall_2016/ARMLPower_Fall_2016_reading.pdf

3.w. Nihilist [Polybius Square] (Also called a Nihilist Substitution cipher) Div B Div C

The Nihilist cipher works by first building a Polybius Square based on a keyword with an alphabet that skips the letter J. Based on this square, each letter gets a unique 2 digit number based on the row/column that it appears. A separate key is then used to encode each character of the plain text by adding the value for that letter to the value associated with the corresponding key in order to generate an encoding number. As such, each cipher text value will be a number from 22 to 110.

References:

- https://www.cryptogram.org/downloads/aca.info/ciphers/NihilistSubstitution.pdf
- https://toebes.com/Flynns/Flynns-19250328.htm
- http://www.crypto-it.net/eng/simple/nihilist.html
- https://en.wikipedia.org/wiki/Nihilist_cipher
- https://www.dcode.fr/nihilist-cipher
- https://cryptii.com/pipes/nihilist-cipher
- https://asecuritysite.com/cipher/nihlist

3.x. Complete Columnar [Transposition] Div B Div C

The Complete Columnar cipher works by writing the cipher into a rectangular block by filling the rows, assigning a key at the top of the columns and then reading the cipher text out by columns in the order of the key.

References:

- https://www.cryptogram.org/downloads/aca.info/ciphers/CompleteColTransposition.pdf

- https://en.wikipedia.org/wiki/Transposition_cipher#Columnar_transposition
- https://www.dcode.fr/columnar-transposition-cipher
- https://www.geeksforgeeks.org/columnar-transposition-cipher/
- https://crypto.interactive-maths.com/columnar-transposition-cipher.html
- https://rumkin.com/tools/cipher/columnar-transposition/

4. Caesar Div A Div B

With a Caesar cipher, there are three strategies depending on the Cipher Text. Fortunately, you can use the Vigenère table to do this lookup.

1. If you have a single letter word, it is likely to be either A or I, so determine the offset from the letter in the Cipher text and use that mapping to evaluate any other word in the cipher. If it reads correctly, then you can proceed to decode the remainder of the text.
2. If there is a double letter word, a simple trick is to test it quickly which requires looking up only eight characters: Six letters mapping the beginning (A B I M O U) and two letters at the end (O E). The letters are for the beginning and for the end. The starting letters Match against As/At/An/Am, Be/By, In/It/Is/If, Me/My, Of/Or/On, and Up/Us. The ending letters Match against dO/gO/nO/sO/tO and hE/wE. First look up the match for the starting letters against ABIMOU and see what the secondary letter would make the word be. Do the same for the two ending letters (OE) and see what the corresponding starting letter would be. With whatever offset produces the most logical words, test another word and make sure it makes sense. If it reads correctly then proceed to decode the remainder of the text.
3. In the case where there are no single or double letter words, it is necessary to brute force doing the lookup. Start with the second row of the table and go through the alphabet decoding characters one at a time until a word makes sense. An alternate way to do it is to write the cipher text on the page and then write the subsequent letters one below another one column at a time until you see a word make sense. For example, starting with RIK you could do:

RIK
SJL
TKM
ULN
VMO
WNP
XOQ
YPR
ZQS
ART

To see that the word is ART and the offset is 9.

5. Aristocrat Div A Div B Div C

5.a. General Solving Rules

In general, the strategy for an Aristocrat is:

- Fill in letters from any clues you are given
- Look for single letter words which will generally be **A** or **I**
- Check the frequency. The most common letters in English are **ETAOIN**.
- Look for contractions (**DON'T**, **DOESN'T**)
- Look for two and three letter words
- Look for patterns "**IT IS**" and "**THAT**" are good ones
- Look for double letters
- If you have a K1 or K2 alphabet, take advantage of the pattern to figure out additional letters

A much more detailed guide can be found on Puzzle Baron's Cryptograms site at https://cryptograms.puzzlebaron.com/tutorial.php

5.b. Solving with a K1 Alphabet

Sometimes an Aristocrat or Patristocrat will be encoded with a K1 alphabet instead of a random alphabet. This can make it much easier to solve once you have identified a few letters.

To understand what this means you must look at how the letters are chosen to replace the original text. This process goes as follows:

- When creating the encryption, pick a code word or phrase. For example, we choose a phrase of "**ALPHABET SOUP**" as our encryption code word.
- Eliminate all duplicate letters in the phrase. In this case the letter **A** appears twice (once at the start and after the **H**) and the letter **P** appears twice (third letter and at the end). We also drop any spaces and punctuation to end up with **ALPHBETSOU**
- Pick an offset in the alphabet to place the code word. In this example, we will start at offset 5 meaning that we shift the alphabet by 5 characters. This means that we will map the letter **A** to **F**, **L** to **G** etc. This means the word **THE** would be encoded as **LIK**

	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
Frequency																										
Replacement						A	L	P	H	B	E	T	S	O	U											

Next, we fill in the remainder of the alphabet starting at the end of the phrase with the start of the alphabet and wrapping back to the beginning to use up all the characters. However, in this case since we already used the letters A, B and E in our phrase, we would start with **C D F G** etc. This gives us a mapping of

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

Applying the knowledge

To see how this would be useful, let's take a simple Aristocrat which was encoded with a K1 alphabet. We know that because of the K1 in the replacement table.

MQKAI FXLA MVRUI DRBQ BQI DXAUN.

RB'M K MFVHXU XO OARIWNMQRY KWN YIKJI.

K1	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
Frequency	4	3		2		2		1	6	1	4	1	5	3	2		4	5			3	2	2	4	2	
Replacement																										

Taking a quick look, the apostrophe and single letter word at the start of the second sentence suggests **IT'S A**.

MQKAI FXLA MVRUI DRBQ BQI DXAUN.
S A S I IT T
RB'M K MFVHXU XO OARIWNMQRY KWN YIKJI.
IT'S A S I S I A A .

K1	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
Frequency	4	3		2		2		1	6	1	4	1	5	3	2		4	5			3	2	2	4	2	
Replacement		T									A		S					I								

The three-letter word **BQI** starts with a **T** and the **I** is the most frequent letter, so we can assume that it is **THE**. Filling that in gives us

MQKAI FXLA MVRUI DRBQ BQI DXAUN.
SHA E S I E ITH THE
RB'M K MFVHXU XO OARIWNMQRY KWN YIKJI.
IT'S A S IE SHI A EA E.

K1	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
Frequency	4	3		2		2		1	6	1	4	1	5	3	2		4	5			3	2	2	4	2	
Replacement		T							E		A		S				H	I								

This is where we get a huge break because we know that it is a K1 alphabet. If you look at the **E A** and **S** you notice that the **A** is after the **E** and the **S** is only one letter away from the **A**. This tells us that they must be part of the key phrase. Looking further we see the **HI** combination which we can guess is part of the remaining alphabet. Furthermore counting the letters after the **H I**, we try **J K L M N O P Q R** (skip the **S** because it was already used) **T** and see that it fits exactly in the space for **S** to **A** giving us a replacement alphabet of:

K1	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
Frequency	4	3		2		2		1	6	1	4	1	5	3	2		4	5			3	2	2	4	2	
Replacement	R	T							E		A		S				H	I	J	K	L	M	N	O	P	Q

MQKAI FXLA MVRUI DRBQ BQI DXAUN.

SHARE O R SMILE ITH THE ORL
RB'M K MFVHXU XO OARIWNMQRY KWN YIKJI.
IT'S A S M OL O RIEN SHIP AN PEA E.

This fills in quite a bit for us and we can readily see that **D** must be **W**, **O** must be **F** and **N** must be **D** giving us:

MQKAI FXLA MVRUI DRBQ BQI DXAUN.
SHARE O R SMILE WITH THE WORLD
RB'M K MFVHXU XO OARIWNMQRY KWN YIKJI.
IT'S A S M OL OF FRIENDSHIP AND PEA E.

K1

	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
Frequency	4	3		2		2		1	6	1	4	1	5	3	2		4	5			3	2	2	4	2	
Replacement	R	T		W					E		A		S	D	F		H	I	J	K	L	M	N	O	P	Q

We can look and know a couple of things. **P** must be **G** because of the single letter gap between the **F** and the **H**. The letters **B** and **C** must be in the key phrase because we started with the letter **D** after the phrase. But we also can see a couple of letters to substitute in the phase. **J** must be **C** to make the word **PEACE** and **FXLA** must be **YOUR**. This gives us:

MQKAI FXLA MVRUI DRBQ BQI DXAUN.
SHARE YOUR SMILE WITH THE WORLD
RB'M K MFVHXU XO OARIWNMQRY KWN YIKJI.
IT'S A SYM OL OF FRIENDSHIP AND PEACE.

K1

	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
Frequency	4	3		2		2		1	6	1	4	1	5	3	2		4	5			3	2	2	4	2	
Replacement	R	T		W		Y			E	C	A	U	S	D	F	G	H	I	J	K	L	M	N	O	P	Q

Looking at this, we see that **V** must be between **T** and **W** (we already used the **U**) **X** must be between the **W** and the **Y** which is followed by **Z**. This leaves **H** to map to the letter **B**.

MQKAI FXLA MVRUI DRBQ BQI DXAUN.
SHARE YOUR SMILE WITH THE WORLD
RB'M K MFVHXU XO OARIWNMQRY KWN YIKJI.
IT'S A SYMBOL OF FRIENDSHIP AND PEACE.

K1

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

This gives us our solution and you can see that the keyword was "**BECAUSE**."

Note that just because it is a K1 alphabet doesn't mean that you must solve it that way, it just serves as a hint to make it easier.

5.c. Solving with a K2 Alphabet

Sometimes an Aristocrat or Patristocrat will be encoded with a K2 alphabet instead of a random alphabet. This can make it much easier to solve once you have identified a few letters.

To understand what this means you must look at how the letters are chosen to replace the original text. This process goes as follows:

- When creating the encryption, pick a code word or phrase. For example, we choose a phrase of "**ALPHABET SOUP**" as our encryption code word.
- Eliminate all duplicate letters in the phrase. In this case the letter **A** appears twice (once at the start and after the **H**) and the letter **P** appears twice (third letter and at the end). We also drop any spaces and punctuation to end up with **ALPHBETSOU**
- Pick an offset in the alphabet to place the code word. In this example, we will start at offset 5 meaning that we shift the alphabet by 5 characters. This means that we will map the letter **A** to **F**, **L** to **G** etc. This means the word **THE** would be encoded as **LIK**

Replacement						A	L	P	H	B	E	T	S	O	U										
K2	**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**
Frequency																									

Next, we fill in the remainder of the alphabet starting at the end of the phrase with the start of the alphabet and wrapping back to the beginning to use up all the characters. However, in this case since we already used the letters A, B and E in our phrase, we would start with **C D F G** etc. This gives us a mapping of

Replacement	V	W	X	Y	Z	A	L	P	H	B	E	T	S	O	U	C	D	F	G	I	J	K	M	N	Q	R
K2	**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**
Frequency																									

One significant difference to pay attention to with a K2 table is that the Frequency is associated with the letter above it and not the letter that maps to it.

Applying the knowledge

To see how this would be useful, let's take an example from the 2023 North Carolina Division B Regional 2 Test Question #20. Note that not only do they tell us that it is encoded with a K2 alphabet, we can also see it by the K2 in the replacement table.

20) **[263 points]** Decode a quote by Peter DeVries that has been encoded using the Aristocrat Cipher and a K2 alphabet. You are told that it contains the word **LIKE** in it.

RSK THAUKPQK AQ FADK Z QZLK RJ VSAIS RSKPK AQ Z

IJGNAHZRAJH - NTR RSK IJGNAHZRAJH AQ FJIDKC TM AH

RSK QZLK.

Replacement																									
K2	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
Frequency	11		1	2		2	2	6	4	6	11	2	1	3		2	6	8	6	3	1	1				6

Since they tell us that we can find the word **LIKE** in it, there are only three places with two possibilities where it can be. The first is **FADK** and the other two occurrences of **QZLK** can be it. Since they both end in **K**, (plus we can see that there are 11 of them) we know for certain that **E** maps to **K** and fill it in to start. We also put the **K** ABOVE the **E** in the Replacement row of the table and mark out the 11 under the **K**. This is a good example showing how you need to only map the frequency to the bottom letter as there are zero occurrences of the Ciphertext letter **E**.

RSK THAUKPQK AQ FADK Z QZLK RJ VSAIS
RSKPK AQ Z
E E E E E
E E
IJGNAHZRAJH - NTR RSK IJGNAHZRAJH AQ
FJIDKC TM AH
E
E
RSK QZLK.
E E

Replacement					K																				
K2	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
Frequency	11		1	2		2	2	6	4	6	~~11~~	2	1	3		2	6	8	6	3	1	1				6

Another thing stands out immediately. The cipher starts with **RSK** (**??E**) and we also see **RSKPK** (**??E?E**). Given the high frequency of **R**(8) and thinking about pattern words, we will guess that they are **THE** and **THERE** respectively. Mapping **R** to **T**, **S** to **H** and **P** to **R**, we put the respective letters in the top row and cross out the frequency to track them.

RSK THAUKPQK AQ FADK Z QZLK RJ VSAIS
RSKPK AQ Z
THE E E E E T H H
THERE
IJGNAHZRAJH - NTR RSK IJGNAHZRAJH AQ
FJIDKC TM AH
T T THE T
E

RSK QZLK.
THE E

Replacement					K			S									P		R						
K2	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
Frequency	11		1	2		2	2	6	4	6	~~11~~	2	1	3		~~2~~	6	~~8~~	~~6~~	3	1	1				6

With this information in hand, we can immediately see where part of the keyword is and the mapping of another letter. Note the single space between the **P** and the **R**. Since there is only one letter of the alphabet between them, it tells us it must be **Q** which will map to **S**. This makes sense since there are 6 **Q**s in the cipher and **S** is a semi-high frequency. We can also see the **K** and **S** off to the left with only a couple of letters between them. Given how far apart they are we must assume that they are part of the keyword. Let's fill in the **Q** and mark the keyword so we can track it.

RSK THAUKPQK AQ FADK Z QZLK RJ VSAIS RSKPK AQ Z
THE E SE S E S E T H H THERE S
IJGNAHZRAJH - NTR RSK IJGNAHZRAJH AQ FJIDKC TM AH
T T THE T S E
RSK QZLK.
THE S E

Replacement					K			S									P	Q	R						
K2	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
Frequency	11		1	2		2	2	6	4	6	~~11~~	2	1	3		~~2~~	~~6~~	~~8~~	~~6~~	3	1	1				6

Filling in the **Q** helped in two ways. First it eliminated **QZLK** as mapping to **LIKE** from the clue which means **FADK** must be **LIKE**. We also see **AQ** mapping to **?S** which must either be IS or **AS**, but since **A** can't map to itself it also confirms that **A** must map to **I**. So we fill in **F** mapping to **L**, **A** mapping to **I** and **D** mapping to **K**.

RSK THAUKPQK AQ FADK Z QZLK RJ VSAIS RSKPK AQ Z
THE I ERSE IS LIKE S E T HI H THERE IS
IJGNAHZRAJH - NTR RSK IJGNAHZRAJH AQ FJIDKC TM AH
I TI T THE I TI IS L KE I

RSK QZLK.
THE S E

Replacement					K			S	A	bc	D	F						P	Q	R						
K2	**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**
Frequency	~~11~~		1	~~2~~		~~2~~	2	6	4	6	~~11~~	2	1	3		~~2~~	~~6~~	~~8~~	~~6~~	3	1	1				6

Seeing the **A?DF** in the replacement line of the table confirms our suspicion that **K** and **S** are part of the keyword. With one spot between the **A** and **D** on the replacement line, we know that **B** or **C** must map to **J**. Since we have no occurrences of **B** in the cipher text but a single occurrence of **C** in the cipher text at the end of a word **FJIDKC** (**L???E?**) it makes no sense for **C** to be **J** (since no common words end with **EJ**) which tells us that **C** is part of the keyword and that **B** must map to **J**.

RSK THAUKPQK AQ FADK Z QZLK RJ VSAIS
RSKPK AQ Z
THE I ERSE IS LIKE S E T HI H
THERE IS
IJGNAHZRAJH - NTR RSK IJGNAHZRAJH AQ
FJIDKC TM AH
I TI T THE I TI IS L
KE I
RSK QZLK.
THE S E

Replacement					K			S	A	B	D	F						P	Q	R						
K2	**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**
Frequency	~~11~~		1	~~2~~		~~2~~	2	6	4	6	~~11~~	2	1	3		~~2~~	~~6~~	~~8~~	~~6~~	3	1	1				6

We also see the single letter **Z** which would either be **I** or **A**, but since we already know the mapping for **I**, it must be the letter **A**. Placing the **Z** there tells us that it is also the end of the alphabet and the start of the keyword on the next letter.

RSK THAUKPQK AQ FADK Z QZLK RJ VSAIS
RSKPK AQ Z
THE I ERSE IS LIKE A SA E T HI H
THERE IS A
IJGNAHZRAJH - NTR RSK IJGNAHZRAJH AQ
FJIDKC TM AH
I ATI T THE I ATI IS L
KE I
RSK QZLK.
THE SA E

Replacement	Z				K			S	A	B	D	F						P	Q	R						
K2	**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**
Frequency	~~11~~		1	~~2~~		~~2~~	2	6	4	6	~~11~~	2	1	3		~~2~~	~~6~~	~~8~~	~~6~~	3	1	1				~~6~~

This turns out to be a very lucky break. If you count the number of letters between the **PQR** and the wrap around the table to the **Z**, we see 6 blank letters. Between **R** and **Z** there are 7 letters in the alphabet, but since **S** is already taken (mapping to **H**) it means that there are 6 remaining letters **TUVWXY** which we can fill in providing mappings for **T** as **U**, **U** as **V** and **Y** as **Z** that we can fill in the cipher.

RSK THAUKPQK AQ FADK Z QZLK RJ VSAIS RSKPK AQ Z
THE U IVERSE IS LIKE A SA E T WHI H THERE IS A
IJGNAHZRAJH - NTR RSK IJGNAHZRAJH AQ FJIDKC TM AH
I ATI UT THE I ATI IS L KE U I
RSK QZLK.
THE SA E

Replacement	Z				K			S	A	B	D	F						P	Q	R	T	U	V	W	X	Y
K2	**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**
Frequency	~~11~~		1	~~2~~		~~2~~	2	6	4	6	~~11~~	2	1	3		~~2~~	~~6~~	~~8~~	~~6~~	~~3~~	~~1~~	~~1~~				~~6~~

We know a couple of things. The Keyword is **???K??S** and also has the letters **C** and **E** in it based on the gaps in the alphabet. Also, we have 5 spaces between **F** and **P** and 8 letters to fit into them (**GHIJLMNO** since **K** is already taken). Since three of those letters are in the keyword, it means each space only has 4 possible letters. One of **GHIJ** will map to **M**, **HIJK** to **N**, … **LMNO** to **Q**. Let's fill them in to see what we get

RSK THAUKPQK AQ FADK Z QZLK RJ VSAIS RSKPK AQ Z
THE U IVERSE IS LIKE A SA E T WHI H THERE IS A
IJGNAHZRAJH - NTR RSK IJGNAHZRAJH AQ FJIDKC TM AH
I ATI UT THE I ATI IS L KE U I
RSK QZLK.
THE SA E

Replacement	Z				K			S	A	B	D	F	ghjj	hijk	ijkl	jklm	lmno	P	Q	R	T	U	V	W	X	Y
K2	**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**
Frequency	~~11~~		1	~~2~~		~~2~~	2	6	4	6	~~11~~	2	1	3		~~2~~	~~6~~	~~8~~	~~6~~	~~3~~	~~1~~	~~1~~				~~6~~

Of those that we just filled in, both **H** (which can map to **M** or **N**) and **J** (which can map to **M N O** or **P**) occur 6 times each in the cipher. Since **H** has only two possibilities, we try it first to see whether **M** or **N** makes more sense. Looking at the second word in the cipher **THAUKPQK** (**U?IVERSE**) it is obvious that **H** must be **N**. This immediately tells us that **G** must be **M** to keep the alphabet going and we can fill in those letters.

RSK THAUKPQK AQ FADK Z QZLK RJ VSAIS
RSKPK AQ Z
THE UNIVERSE IS LIKE A SA E T WHI H
THERE IS A
IJGNAHZRAJH - NTR RSK IJGNAHZRAJH AQ
FJIDKC TM AH
M INATI N UT THE M INATI N IS L
KE U IN
RSK QZLK.
THE SA E

Replacement	Z				K			S	A	B	D	F	G	H	ijkl	jklm	lmno	P	Q	R	T	U	V	W	X	Y
K2	**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**
Frequency	~~11~~		1	~~2~~		~~2~~	~~2~~	~~6~~	4	6	~~11~~	2	1	3		~~2~~	~~6~~	~~8~~	~~6~~	~~3~~	~~1~~	~~1~~				~~6~~

Looking at the frequency table, we see only one high frequency letter which we haven't mapped – **J**. Of the top 10 most frequent letters: **ETAOIN SRHL** we have mapped everything except the letter **O**, so let's see if the letter **J** maps to **O**. Looking at the first occurrence **RJ** (**T?**) we see a perfect match for **TO** so we can fill that in.

RSK THAUKPQK AQ FADK Z QZLK RJ VSAIS
RSKPK AQ Z
THE UNIVERSE IS LIKE A SA E TO WHI H
THERE IS A
IJGNAHZRAJH - NTR RSK IJGNAHZRAJH AQ
FJIDKC TM AH
OM INATION UT THE OM INATION IS LO
KE U IN
RSK QZLK.
THE SA E

Replacement	Z				K			S	A	B	D	F	G	H	J	lmn	mno	P	Q	R	T	U	V	W	X	Y
K2	**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**
Frequency	~~11~~		1	~~2~~		~~2~~	~~2~~	~~6~~	4	~~6~~	~~11~~	2	1	3		~~2~~	~~6~~	~~8~~	~~6~~	~~3~~	~~1~~	~~1~~				~~6~~

This fills in quite a bit and we could pretty much guess the cipher, but we really would like to figure out the keyword which we know to be **???K??S** and also has the letters **C**, **E** and **I** in it along with two letters from the group **LMNO**. However, the **VSAIS** (**WHI?H**) in the cipher text is clearly begging to be filled in with the letter **C** giving us the mapping of 4 more characters

RSK THAUKPQK AQ FADK Z QZLK RJ VSAIS RSKPK AQ Z
THE UNIVERSE IS LIKE A SA E TO WHICH THERE IS A
IJGNAHZRAJH - NTR RSK IJGNAHZRAJH AQ FJIDKC TM AH
COM INATION UT THE COM INATION IS LOCKE U IN
RSK QZLK.
THE SA E

Replacement	Z		I		K			S	A	B	D	F	G	H	J	lmn	mno	P	Q	R	T	U	V	W	X	Y
K2	**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**
Frequency	~~11~~		1	~~2~~		~~2~~	~~2~~	~~6~~	~~4~~	~~6~~	~~11~~	2	1	3		~~2~~	~~6~~	~~8~~	~~6~~	~~3~~	~~1~~	~~1~~				~~6~~

We also clearly see that **IJGNAHZRAJH** (**COM?INATION**) must be **COMBINATION** mapping **N** to **B** so we fill that in.

RSK THAUKPQK AQ FADK Z QZLK RJ VSAIS RSKPK AQ Z
THE UNIVERSE IS LIKE A SA E TO WHICH THERE IS A
IJGNAHZRAJH - NTR RSK IJGNAHZRAJH AQ FJIDKC TM AH
COM INATION UT THE COM INATION IS LOCKE U IN
RSK QZLK.
THE SA E

Replacement	Z	N	I		K			S	A	B	D	F	G	H	J	lm	mo	P	Q	R	T	U	V	W	X	Y
K2	**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**
Frequency	~~11~~		1	~~2~~		~~2~~	~~2~~	~~6~~	~~4~~	~~6~~	~~11~~	2	1	~~3~~		~~2~~	~~6~~	~~8~~	~~6~~	~~3~~	~~1~~	~~1~~				~~6~~

This leaves us with a keyword of **NI?K??S** and also has the letters **C** and **E** in it along with one of the letters from the group **LMO**. The **C** obviously goes before the **K** and only the **L** makes

sense after the **K** leaving us with a K2 keyword of **NICKLES** that we can use to construct the remainder of the mapping (and solving the cipher)

RSK THAUKPQK AQ FADK Z QZLK RJ VSAIS RSKPK AQ Z
THE UNIVERSE IS LIKE A SAFE TO WHICH THERE IS A
IJGNAHZRAJH - NTR RSK IJGNAHZRAJH AQ FJIDKC TM AH
COMBINATION - BUT THE COMBINATION IS LOCKED UP IN
RSK QZLK.
THE SAFE.

Replacement	Z	N	I	C	K	L	E	S	A	B	D	F	G	H	J	M	O	P	Q	R	T	U	V	W	X	Y
K2	**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**
Frequency	~~11~~		~~1~~	~~2~~		~~2~~	~~2~~	~~6~~	~~4~~	~~6~~	~~11~~	~~2~~	~~1~~	~~3~~		~~2~~	~~6~~	~~8~~	~~6~~	~~3~~	~~1~~	~~1~~				~~6~~

5.d. Solving with a K3 Alphabet

With a K3 alphabet, both the source and replacement alphabets are the same. It is a bit harder to solve with a K3, but there are some hints that help you out.

To understand what this means you must look at how the letters are chosen to replace the original text. This process goes as follows:

- When creating the encryption, pick a code word or phrase. For example, we choose a keyword of "**MACHINERY**" as our encryption code word.

We then build up an alphabet starting with the keyword followed by all the other letters which weren't used:

MACHINERYBDFGJKLOPQSTUVWXZ

Pick an offset to shift the second alphabet by. If we pick an offset of 1 then we get a mapping like:

MACHINERYBDFGJKLOPQSTUVWXZ *Ciphertext*
Z**MACHINERY**BDFGJKLOPQSTUVWX *Plaintext*

When you build out the replacement table, you will notice that the keyword mostly disappears

K3	**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**
Frequency																										
Replacement	M	Y	A	B	N	D	F	C	H	G	J	K	Z	I	L	O	P	E	Q	S	T	U	V	W	R	X

However, as you can see where the highlighted letters end up, because of the offset of 1, only the mapping of the **M** and the **Y** don't correspond to

another letter of the keyword. But all of the other letters map to a closely shifted letter in groups. For example, you see **STUVW** and **TUVWX** as a nice clean set and **KL**/**JK** as another nice pair mapping

You want offsets that produce some overlap between the letters. The toughest K3 would be a 13-character phrase with an offset of 13 so that there is no overlap. Small offsets mean that they can see the sequence of characters more readily. For this example, we will use an offset of 3 which would give us

MACHINERYBDFGJKLOPQSTUVWXZ *Ciphertext*

WXZ**MACHINERY**BDFGJKLOPQSTUV *Plaintext*

This gives us a replacement table that looks like:

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

Which you should notice is quite a bit different from the offset of 1 replacement table. Also, six of the characters map to other letters in the replacement set which is what you would expect with a shift of 3 for a 9-character keyword.

Applying the knowledge

To see how this would be useful, let's take a simple Aristocrat which was encoded with a K3 alphabet. We know that because of the K1 in the replacement table. We are asked to solve the K3 keyword and are giving a solution box of:

WESVB RDDRWIWRSYV IYJ XYBIVRYBVV FSX
IDB KINBJ MRWE
IDB BZRJBYNB WEIW FSX EIZB IY
IVVRLYHBYW WS KXQKRQQ.

K3

	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
Frequency		11		4	4	2		1	10	3	3	1	1	2			3	8	5			7	8	4	8	2
Replacement																										

Our immediate guess is that the high frequency of **B** suggests that it map to **E**.

WESVB RDDRWIWRSYV IYJ XYBIVRYBVV FSX
IDB KINBJ MRWE
E E E
E E
IDB BZRJBYNB WEIW FSX EIZB IY
IVVRLYHBYW WS KXQKRQQ.
E E E E E E

.

K3	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
Frequency		11		4	4	2		1	10	3	3	1	1	2			3	8	5			7	8	4	8	2
Replacement		E																								

Looking at the next most frequent letter **I**, we might guess that it is a **T**, but that the **WEIW** in the middle would come out as **WETW** and the only real word that would match that pattern is **HATH**, so we go to the **W** as the next most frequent which gives the word **HATH** and filling in a lot of other possibilities

WESVB RDDRWIWRSYV IYJ XYBIVRYBVV FSX
IDB KINBJ MRWE
TH E TAT A EA E A
E A E TH
IDB BZRJBYNB WEIW FSX EIZB IY
IVVRLYHBYW WS KXQKRQQ.
A E E E E THAT HA E A A E
T T .

K3	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
Frequency		11		4	4	2		1	10	3	3	1	1	2			3	8	5			7	8	4	8	2
Replacement		E			H				A														T			

With this in place, a couple of letters are just staring at us. The **EVV** almost certainly means that **V** must be **S** and that **TS** must be **TO** which gives us:

WESVB RDDRWIWRSYV IYJ XYBIVRYBVV FSX
IDB KINBJ MRWE
THOSE TAT O S A EAS ESS O A
E A E TH
IDB BZRJBYNB WEIW FSX EIZB IY
IVVRLYHBYW WS KXQKRQQ.
A E E E E THAT O HA E A ASS E
T TO .

K3	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
Frequency		11		4	4	2		1	10	3	3	1	1	2			3	8	5			7	8	4	8	2
Replacement		E			H				A										O			S	T			

A few more letters become obvious, but it is worth pointing out that we see the **STUVW** in the table mapping to **O??ST**. This is probably a good clue that TU are likely to map to wither **PQ** with **R** appearing in the keyword or **QR** with **P** appearing in the keyword. Because **TU** don't appear in the cipher text, making a guess won't

help us at this point in time. However, looking at the TATROYS strongly hints that it should be TATIONS which gives us:

WESVB RDDRWIWRSYV IYJ XYBIVRYBVV FSX
IDB KINBJ MRWE
THOSE I ITATIONS AN NEASINESS O A
E A E ITH
IDB BZRJBYNB WEIW FSX EIZB IY
IVVRLYHBYW WS KXQKRQQ.
A E E I EN E THAT O HA E A ASSI N
ENT TO I .

K3

	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
Frequency		11		4	4	2		1	10	3	3	1	1	2			3	8	5			7	8	4	8	2
Replacement		E			H				A									I	O			S	T		N	

We don't get much help with the K3 here, but several words are just begging to be filled in:
A few more letters become obvious, but it is worth pointing out that we see that IDDITATIONS, XNEASINESS and ASSILNHENT must be IRRITATIONS, UNEASINESS and ASSIGNMENT respectively which gives us:

WESVB RDDRWIWRSYV IYJ XYBIVRYBVV FSX
IDB KINBJ MRWE
THOSE IRRITATIONS AN UNEASINESS OU
ARE A E ITH
IDB BZRJBYNB WEIW FSX EIZB IY
IVVRLYHBYW WS KXQKRQQ.
ARE E I EN E THAT OU HA E A
ASSIGNMENT TO U I .

K3

	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
Frequency		11		4	4	2		1	10	3	3	1	1	2			3	8	5			7	8	4	8	2
Replacement		E		R	H			M	A			G						I	O			S	T	U	N	

This tells us a little more about the K3. The **HI** mapping to **MA** strongly hints that one or more of those characters are in the keyword. The **VWXY** mapping to **STUN** tells us that either **Y** or **N** (or both) are in the keyword. But we still have a few more obvious letters to fill in: ANJ must be AND, FOU must be YOU, HAZE must be HAVE and EZIJENNE must be EVIDENCE which gives us:

WESVB RDDRWIWRSYV IYJ XYBIVRYBVV FSX
IDB KINBJ MRWE
THOSE IRRITATIONS AND UNEASINESS YOU
ARE ACED ITH
IDB BZRJBYNB WEIW FSX EIZB IY
IVVRLYHBYW WS KXQKRQQ.

ARE EVIDENCE THAT YOU HAVE AN
ASSIGNMENT TO U I .

K3	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
Frequency		11		4	4	2		1	10	3	3	1	1	2			3	8	5			7	8	4	8	2
Replacement		E		R	H	Y		M	A	D		G		C				I	O			S	T	U	N	V

A couple of obvious things come out from looking at this. We know for certain that the letter **N** or **Y** (or both) is a part of the keyword by looking at the **VWXYZ** mapping to **STUNV**. We also know that **VWXZ** are not part of the keyword. We will solve the keyword in a minute, but the letters we filled in pretty much give away the remainder of the cipher:

WESVB RDDRWIWRSYV IYJ XYBIVRYBVV FSX IDB KINBJ MRWE
THOSE IRRITATIONS AND UNEASINESS YOU ARE FACED WITH
IDB BZRJBYNB WEIW FSX EIZB IY IVVRLYHBYW WS KXQKRQQ.
ARE EVIDENCE THAT YOU HAVE AN ASSIGNMENT TO FULFILL.

K3	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
Frequency		11		4	4	2		1	10	3	3	1	1	2			3	8	5			7	8	4	8	2
Replacement		E		R	H	Y		M	A	D	F	G	W	C			L	I	O			S	T	U	N	V

To figure out the K3 keyword, we need to take a quick look at the letters in the mapping to see what we can group up. We start by collecting the groups of letters that are obvious sequences and write them down.

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

Since both sequences must match, we can build a few more clusters by lining up what we know under them. Using three lines of the sequence helps to align them quicker. What you are looking for is where letters must line up relative to others and figure out the shift of the letters. Once you know the shift for certain, you can use it to place obvious letters. With our basic set gathered, we write down the letters under them that we know. If you don't know something, a ? is pretty useful because it MUST be some letter, you just don't know what it is, but when you do find out, it fills it in for another space.

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

H I M N RY? T ? G A ? O?? C S

Next, we pull out the ones which we know for certain are in the keyword and push them together. The **RY** is certainly in the keyword because of the **JKL/DFG**. It also tells us the **E** is in the keyword. So, a little rewrite of the letters pushing a few of the ones we know are together.

A B C D E F G H I **JKL** M N O P **QSTUVWXZ** R Y
? E ? R H Y ? M A **DFG** W C **LO STUV** I N
? H ? I M N ? W ? **RY?** T ? **G? O??S** A C

It is clear at this point in time that the sequence **JKLOPQSTUVWXZ** is the end of the list so we can reorganize it as

A B C D E F G H I **JKLOPQSTUVWXZ** M N R Y
? E ? R H Y ? M A **DFG??LO??STUV** W C I N
? H ? I M N ? W ? **RY???G???O??S** T ? A C

We fill in the ones we now know - **JK** must correspond to **OP** because it is right before the **LO**

A B C D E F G H I JKLOPQSTUVWXZ M N R Y
? E ? R H Y ? M A DFG**JK**LO**PQ**STUV W C I N
? H ? I M N ? W ? RY?**DF**GJ**KL**OPQS T ? A C

Moving backwards we can pull in **DFG** in front of **JKL** filling from the others we know

A B C **DFG**JKLOPQSTUVWXZ E H I M N R Y
? E ? **RY?**DFGJKLOPQSTUV H M A W C I N
? H ? **IN?**RY?DFGJKLOPQS M W ? T ? A C

Now we can go forwards because we know **W** need to be after **TUV** on the second line and it tells us that the first letter of the keyword is **M**

A B C DFGJKLOPQSTUVWXZ**M** E H I N R Y
? E ? RY?DFGJKLOPQSTUV**W** H M A C I N
? H ? IN?RY?DFGJKLOPQS**T** M W ? ? A C

To figure what goes after **M**, we have only two letters which aren't identified, **A** and **C**. Since MC doesn't make a good word, we will go with **MA** which will have to map to **X** and subsequently **U**

B C DFGJKLOPQSTUVWXZM**A** E H I N R Y
E ? RY?DFGJKLOPQSTUVW**X** H M A C I N
H ? IN?RY?DFGJKLOPQST**U** M W ? ? A C

We also know that after **STU** on the bottom line, we need to have **VWXZ** but only the **W** is known (which is good because it also puts the **M** in the right place).

B C DFGJKLOPQSTUVWXZMA**-H** E I N R Y
E ? RY?DFGJKLOPQSTUVWX**-M** H A C I N
H ? IN?RY?DFGJKLOPQSTU**-W** M ? ? A C

From looking at this, we know the shift of the letters to be 3, so we can order the letters that we have remaining in place. The **H** in the second row must be three after the **H** in the first row. The **A** in the second row must be three after the **A** in the first row. Then

the **I** in the second row should be three after the **I** in the first row giving us:

```
B  C  DFGJKLOPQSTUVWXZMA-H**I-ER** N  Y
E  ?  RY?DFGJKLOPQSTUVWX-M**A-HI** C  N
H  ?  IN?RY?DFGJKLOPQSTU-W**?-MA** ?  C
```

With the three **C**'s staring at us and a gap of three after the **MA**, **HI** and **ER**, we know that they have to go there so we put them in place.

```
B  DFGJKLOPQSTUVWXZMA**C**HI**N**ER**Y**
E  RY?DFGJKLOPQSTUVWX**?**MA**C**HI**N**
H  IN?RY?DFGJKLOPQSTU**?**W**?**?MA**C**
```

At this point, the answer comes out as being **MACHINERY**.

6. Patristocrat Div B Div C

6.a. General solving approach

In general, there are three basic strategies for solving a Patristocrat. Because there are no word spacings, many of the Aristocrat rules don't apply

1. Frequency is your friend. Look for the high frequency letters to match them with **ETAOIN**.

6.b. Solving with a K1 Alphabet

Question #5 on 2018 Sample 7 is a Patristocrat with a K1 alphabet and a simple clue:

---

5) **[250 Points]** Solve this K1 key encoded Patristocrat which is a quote by Barbara Tuchman in "*Can History Be Served Up Hot?*" and has the word **THE** in it three times and ends with **HEARD**.

JFHVI DHESD LHLBC UJOUI SIHSJ FHDJF CISVD SRLMD
OHILJ FHJDH HOIJF HBDOG HWCRM SDHUJ XFOEF MHRRX
OJFSV JKHOI NFHCD L

K1	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
Frequency		2	4	9	2	9	1	15	7	10	1	5	3	1	7			4	7		3	3	1	2		
Replacement																										

Here's one approach to solving it that focuses more heavily on the K1 key as a major clue.

1. Since we are given that **FHCDL** corresponds to **HEARD**, we can go through and make that substitution globally as well as put it in our replacement below

JFHVI DHESD LHLBC UJOUI SIHSJ FHDJF CISVD SRLMD
HE RE R DED A E HER H A R D R
OHILJ FHJDH HOIJF HBDOG HWCRM SDHUJ XFOEF MHRRX
E D HE RE E H E R E A RE H H E

OJFSV JKHOI NFHCD L
H E HEAR D

K1	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
Frequency		2	4	9	2	9	1	15	7	10	1	5	3	1	7			4	7		3	3	1	2		
Replacement			A	R		H		E				D														

2. Next, we look for the locations of **THE** and see that **J** just correspond to **T** which is good because **J** also has a high frequency count. We fill that Information in to get:

JFHVI DHESD LHLBC UJOUI SIHSJ FHDJF CISVD SRLMD
THE RE R DED A T E T HERTH A R D R
OHILJ FHJDH HOIJF HBDOG HWCRM SDHUJ XFOEF MHRRX
E DT HETRE E TH E R E A RE H H E
OJFSV JKHOI NFHCD L
TH T E HEAR D

K1	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
Frequency		2	4	9	2	9	1	15	7	10	1	5	3	1	7			4	7		3	3	1	2		
Replacement			A	R		H		E		T		D														

3. Looking at the key, we have quite a few clues. Because we have the **H** and **E** between the **R** and the **T**, we know that all of them are part of the key word. Along with that since the **A** is right before the **R**, we also know that it is part of the K1 key word. Looking at the unused letter for **A**, we could make a good guess that it is the letter **Z** which means that our keyword goes from at least **B** to **J** as **?AR?H?E?T** which we mark giving us:

JFHVI DHESD LHLBC UJOUI SIHSJ FHDJF CISVD SRLM
THE RE R DED A T E T HERTH A R D
OHILJ FHJDH HOIJF HBDOG HWCRM SDHUJ XFOEF MHRR
E DT HETRE E TH E R E A RE T H H E
OJFSV JKHOI NFHCD L
TH T E HEAR D

K1	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
Frequency		2	4	9	2	9	1	15	7	10	1	5	3	1	7			4	7		3	3	1	2		
Replacement	Z		A	R		H		E		T		D														

4. Looking at the unused letter at **T** and counting backwards from **Z** we could make a good guess that **T** stands for **Q** which would mean that **TUVWXYZ** maps to **QSUVWXY** because **R** and **T** were already used. Filling this in gives us:

```
JFHVI DHESD LHLBC UJOUI SIHSJ FHDJF CISVD SRLMD
THEU  RE  R DED A ST S    E T HERTH A  UR   D R
OHILJ FHJDH HOIJF HBDOG HWCRM SDHUJ XFOEF MHRRX
 E DT HETRE E  TH E R    EVA    REST WH  H  E  W
OJFSV JKHOI NFHCD L
 TH U T E    HEAR D
```

K1	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
Frequency		2	4	9	2	9	1	15	7	10	1	5	3	1	7			4	7		3	3	1	2		
Replacement	Z		A	R		H		E		T		D								Q	S	U	V	W	X	Y

5. Looking at the remaining letters between D and Q we see that there must be three gaps. Likewise, we can also see that the 4th letter much come from the K slot. This gives us K could be either B or C, M must be one of FGIJ (H was already used), N is GIJK, etc. We mark the Information down and then look to see if any of them make sense.

```
JFHVI DHESD LHLBC UJOUI SIHSJ FHDJF CISVD SRLMD
THEU  RE  R DED A ST S    E T HERTH A  UR   D R
OHILJ FHJDH HOIJF HBDOG HWCRM SDHUJ XFOEF MHRRX
 E DT HETRE E  TH E R    EVA    REST WH  H  E  W
OJFSV JKHOI NFHCD L
 TH U T E    HEAR D
```

K1	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
Frequency		2	4	9	2	9	1	15	7	10	1	5	3	1	7			4	7		3	3	1	2		
Replacement	Z		A	R		H		E		T	bc	D	fgij	gijk	ijkl	jklm	klmn	lmno	mnop	Q	S	U	V	W	X	Y

6. Some obvious ones stand out. Looking at the **N** right before **HEARD** at the end, we have choices of **GIJK**. Since we know of few words that end in either **I** or **J** we know it must be a **G** or a **K**. Looking back a bit more we see the **HRRX** which is **ElmnolmnoW** giving us choices of **ELLW EMMW ENNW** or **EOOW**. The only one of those which makes sense is **ELLW** which means **R** must be **L**. Filling these in gives us:

```
JFHVI DHESD LHLBC UJOUI SIHSJ FHDJF CISVD SRLMD
THEU  RE  R DED A ST S    E T HERTH A  UR  LD R
OHILJ FHJDH HOIJF HBDOG HWCRM SDHUJ XFOEF MHRRX
 E DT HETRE E  TH E R   EVAL   REST WH  H  ELLW
OJFSV JKHOI NFHCD L
 TH U T E    gkHEAR D
```

K1	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
Frequency		2	4	9	2	9	1	15	7	10	1	5	3	1	7			4	7		3	3	1	2		
Replacement	Z		A	R		H		E		T	bc	D	fgij	gk	ijkl	J	K	L	mnop	Q	S	U	V	W	X	Y

7. Now that we filled in the **K** as a substitution for **Q**, we know that **N** must be a **G** and **O** must be an **I** and **M** must be an **F**. Filling these in gives us:

```
JFHVI DHESD LHLBC UJOUI SIHSJ FHDJF CISVD SRLMD
THEU  RE  R DED A STIS    E T HERTH A  UR  LDFR
OHILJ FHJDH HOIJF HBDOG HWCRM SDHUJ XFOEF MHRRX
IE DT HETRE EI TH E RI   EVALF  REST WHI H FELLW
OJFSV JKHOI NFHCD L
ITH U T EI  GHEAR D
```

K1	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
Frequency		2	4	9	2	9	1	15	7	10	1	5	3	1	7			4	7		3	3	1	2		
Replacement	Z		A	R		H		E		T	bc	D	F	G	I	J	K	L	mnop	Q	S	U	V	W	X	Y

8. Looking near the end of the second line we see **XFOEFMHRR** mapping to **WHI?HFELL** and could only be **WHICH FELL** meaning that **E** must be a **C**, which this also tells us that **K** must be **B** (because that was the only letter left). Filling that in gives us:

```
JFHVI DHESD LHLBC UJOUI SIHSJ FHDJF CISVD SRLMD
THEU  REC R DED A STIS    E T HERTH A  UR  LDFR
OHILJ FHJDH HOIJF HBDOG HWCRM SDHUJ XFOEF MHRRX
IE DT HETRE EI TH E RI   EVALF  REST WHICH FELLW
OJFSV JKHOI NFHCD L
ITH U TBEI  GHEAR D
```

K1	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
Frequency		2	4	9	2	9	1	15	7	10	1	5	3	1	7			4	7		3	3	1	2		
Replacement	Z		A	R	C	H		E		T	B	D	F	G	I	J	K	L	mnop	Q	S	U	V	W	X	Y

9. At this point, there are only four letters which haven't been mapped: **M N O P**. Looking at the end of the phrase we see **KHOIN** mapping to **BEI?G** leading us to the conclusion that **I** must map to **N**. Filling that in gives us:

```
JFHVI DHESD LHLBC UJOUI SIHSJ FHDJF CISVD SRLMD
THEUN REC R DED A STISN  NE T HERTH AN UR  LDFR
OHILJ FHJDH HOIJF HBDOG HWCRM SDHUJ XFOEF MHRRX
IENDT HETRE EINTH E RI  EVALF  REST WHICH FELLW
OJFSV JKHOI NFHCD L
ITH U TBEIN GHEAR D
```

K1	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
Frequency		2	4	9	2	9	1	15	7	10	1	5	3	1	7			4	7		3	3	1	2		
Replacement	Z		A	R	C	H		E	N	T	B	D	F	G	I	J	K	L	mop	Q	S	U	V	W	X	Y

10. With only **M O** and **P** left, we look at the start of the phrase and see **VIDHESDL** mapping to **UNREC?RD** with the only possible mapping for **S** being **O**. Filling that in gives us:

```
JFHVI DHESD LHLBC UJOUI SIHSJ FHDJF CISVD SRLMD
THEUN RECOR DED  A STISN ONEOT HERTH ANOUR OLDFR
OHILJ FHJDH HOIJF HBDOG HWCRM SDHUJ XFOEF MHRRX
IENDT HETRE EINTH E RI  EVALF ORES T WHICH FELLW
OJFSV JKHOI NFHCD L
ITHOU TBEIN GHEAR D
```

K1	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
Frequency		2	4	9	2	9	1	15	7	10	1	5	3	1	7			4	7		3	3	1	2		
Replacement	Z		A	R	C	H		E	N	T	B	D	F	G	I	J	K	L	O	Q	S	U	V	W	X	Y

11. There are only three letters left to fill in and we could just leave it this way to get 50 points off on the test, but it doesn't take much of a guess with only **M** and **P** left, we read **THE UNRECORDED ?AST** and quickly come to the conclusion that **B** must stand for **P** to read as **THE UNRECORDED PAST** which also means that **G** must be **M**. This works well as we see the

K1 key word is **PARCHMENT**. We complete it with filling them in as:

```
JFHVI DHESD LHLBC UJOUI SIHSJ FHDJF CISVD SRLMD
THEUN RECOR DEDPA STISN ONEOT HERTH ANOUR OLDFR
OHILJ FHJDH HOIJF HBDOG HWCRM SDHUJ XFOEF MHRRX
IENDT HETRE EINTH EPRIM EVALF OREST WHICH FELLW
OJFSV JKHOI NFHCD L
ITHOU TBEIN GHEAR D
```

K1	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
Frequency		2	4	9	2	9	1	15	7	10	1	5	3	1	7			4	7		3	3	1	2		
Replacement	Z	P	A	R	C	H	M	E	N	T	B	D	F	G	I	J	K	L	O	Q	S	U	V	W	X	Y

THE UNRECORDED PAST IS NONE OTHER THAN OUR OLD FRIEND THE TREE IN THE PRIMEVAL FOREST WHICH FELL WITHOUT BEING HEARD.

6.c. Solving with a K2 Alphabet

Sometimes an Aristocrat or Patristocrat will be encoded with a K2 alphabet instead of a random alphabet. This can make it much easier to solve once you have identified a few letters.

To understand what this means you must look at how the letters are chosen to replace the original text. This process goes as follows:

- When creating the encryption, pick a code word or phrase. For example, we choose a phrase of "**ALPHABET SOUP**" as our encryption code word.
- Eliminate all duplicate letters in the phrase. In this case the letter **A** appears twice (once at the start and after the **H**) and the letter **P** appears twice (third letter and at the end). We also drop any spaces and punctuation to end up with **ALPHBETSOU**
- Pick an offset in the alphabet to place the code word. In this example, we will start at offset 5 meaning that we shift the alphabet by 5 characters. This means that we will map the letter **F** to **A**, **G** to **L** etc. This means the word **LINK** would be encoded as **THOE**

Replacement						A	L	P	H	B	E	T	S	O	U											
K2	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
Frequency																										

- Next we fill in the remainder of the alphabet starting at the end of the phrase with the start of the alphabet and wrapping back to the beginning to use up all the characters. However, in this case since we already used the letters **A**, **B** and **E** in our phrase, we would start with **C D F G** etc. This gives us a mapping of:

Replacement	V	W	X	Y	Z	A	L	P	H	B	E	T	S	O	U	C	D	F	G	I	J	K	M	N	Q	R
K2	**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**
Frequency																										

Applying the knowledge

To see how this would be useful, let's take a difficult Patristocrat which was encoded with a K2 alphabet. This is problem 4 on 2020 Sample 5 We know that it is a K2 because of the description and the K2 in the replacement table.

4) **[500 points]** Solve this patristocrat encoded Mark Twain with a K2 alphabet and starts with **I WISH**.

QJQMP QGYEV HWDTI PQWEX HIUMB
DXHBP DBDVY RQXOO

YYHPI DUBQM UQGPI MIXYE OPDXH
BPDBJ QBPYE BQBQX

BIVVI GBQMZ YRIUB C

Replacement																										
K2	**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**
Frequency		12	1	7	4		3	5	8	2			5		3	8	11	2		1	4	4	2	6	7	1

Given the starting information we can fill in the values for **QJMP**.

4) **[500 points]** Solve this patristocrat encoded Mark Twain with a K2 alphabet and starts with **I WISH**.

QJQMP QGYEV HWDTI PQWEX HIUMB
DXHBP DBDVY RQXOO
IWISH I HI S
H I
YYHPI DUBQM UQGPI MIXYE OPDXH
BPDBJ QBPYE BQBQX
H IS I H S H H
W I H I I
BIVVI GBQMZ YRIUB C
IS

Replacement								P	Q									M				J			
K2	**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**
Frequency		12	1	7	4		3	5	8	~~2~~			5		3	~~8~~	~~11~~	2		1	4	4	2	6	7	1

It is very important to pay attention to where you fill in the replacement letters. Unlike a K1 or a Random alphabet Aristocrat/Patristocrat where the frequency is associated with both the replacement and the mapping letter, you can see that you have an extra level of mapping. The **S** mapped to **M** illustrates this well as you can see that there are no **S** present in the cipher text, but there are 5 occurrences of **M**. It is for this reason that it can be easy to get confused and get the wrong mapping.
Filling in these clues also gives us a very interesting observation. The **P** and **Q** right next to each other with the **M** after them and occurring before the **J** tells us that the K2 keyword is near the end of the alphabet mapping.

Replacement								P	Q									M				J			
K2	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
Frequency		12	1	7	4		3	5	8	~~2~~			~~5~~		3	~~8~~	~~11~~	2		1	4	4	2	6	7	1

We can keep that in mind when making guesses for letters. For example, we can surmise that **LNO** are possible letters to map to **G** and **RST** are possibilities to map to **J**. However, there are other clues can work from first. Specifically with high frequency of **B**, we should figure out what it is (we were already told that the second highest frequency **Q** maps to **I**). The obvious first test is **E** for **B**, but looking in the middle of the second line, we would map **JQBP** to be **WIEH**. Unfortunately that doesn't result in any words, parts of words or the end of one word and start of the next, so we try the next letter **T** which gives us **WITH** which makes a lot of sense. As such we guess that **B** maps to **T** and fill it in giving us:

```
QJQMP QGYEV HWDTI PQWEX HIUMB
DXHBP DBDVY RQXOO
IWISH I           HI       ST
TH  T     I
YYHPI DUBQM UQGPI MIXYE OPDXH
BPDBJ QBPYE BQBQX
   H    TIS  I H  S      H    TH
TW ITH   TITI
BIVVI GBQMZ YRIUB C
T      TIS       T
```

Replacement								P	Q									M	B			J			
K2	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
Frequency		~~12~~	1	7	4		3	5	8	~~2~~			~~5~~		3	~~8~~	~~11~~	2		1	4	4	2	6	7	1

As we fill that in, we see **BPDB** which is **TH?T** which tells us that **D** must be **A**, so we fill that in.

QJQMP QGYEV HWDTI PQWEX HIUMB
DXHBP DBDVY RQXOO
IWISH I A HI ST A
TH ATA I
YYHPI DUBQM UQGPI MIXYE OPDXH
BPDBJ QBPYE BQBQX
H A TIS I H S HA
THATW ITH TITI
BIVVI GBQMZ YRIUB C
T TIS T

Replacement	D							P	Q									M	B			J			
K2	**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**
Frequency		~~12~~	1	~~7~~	4		3	5	8	~~2~~			~~5~~		3	~~8~~	~~11~~	2		1	4	4	2	6	7	1

We still haven't seen the mapping of **E**, but the high runners of **I**(8) and **Y**(7) seem like good candidates. However, a very important detail is that we know that whatever maps to **E** must be between **H** and **L**. Why? Because if we assume **D** is part of the alphabet and not the keyword, then the next letters **E**, **F**, and **G** would be minimum to fill in for **B C** and **D**. Likewise going backwards from **H** we have **O** for **G**, **N** for **F** and since **M** and **J** are already used **L** for **E**. Looking at the frequencies of **H I J K** and **L**, that **I** we were looking at pops right out, so we fill it in

QJQMP QGYEV HWDTI PQWEX HIUMB
DXHBP DBDVY RQXOO
IWISH I A E HI E ST A
TH ATA I
YYHPI DUBQM UQGPI MIXYE OPDXH
BPDBJ QBPYE BQBQX
HE A TIS I HE SE HA
THATW ITH TITI
BIVVI GBQMZ YRIUB C
TE E TIS E T

Replacement	D	ef	fg	gh	I	kln	lno	P	Q									M	B			J			
K2	**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**
Frequency		~~12~~	1	~~7~~	4		3	5	~~8~~	~~2~~			~~5~~		3	~~8~~	~~11~~	2		1	4	4	2	6	7	1

Following that logic to look for **O** (since we already **ETAI**), we see the **Y** which has a frequency of 7. It also makes a lot of sense as it would put a **Y** right before where we think the keyword starts. It also looks promising because we have **JQBPYEB** which would read as **WITHO?T** and obviously means that **E** must map to **U** making the word **WITHOUT**. Filling this in we get:

QJQMP QGYEV HWDTI PQWEX HIUMB
DXHBP DBDVY RQXOO
IWISH I OU A E HI U E ST A
TH ATA O I
YYHPI DUBQM UQGPI MIXYE OPDXH
BPDBJ QBPYE BQBQX
OO HE A TIS I HE SE OU HA
THATW ITHOU TITI
BIVVI GBQMZ YRIUB C
TE E TIS O E T

Replacement	D	ef	fg	gh	I	kln	lno	P	Q					Y				M	B	E		J			
K2	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
Frequency		~~12~~	1	~~7~~	~~4~~		3	5	~~8~~	~~2~~			~~5~~		3	~~8~~	~~11~~	2		1	4	4	2	6	7	1

Since we have found where **E** is mapped, we only have three letters between **D** and **I** to map for the alphabet portion. Filling this in we get:

QJQMP QGYEV HWDTI PQWEX HIUMB
DXHBP DBDVY RQXOO
IWISH ICOU D A E HI U DE ST A
DTH ATA O I
YYHPI DUBQM UQGPI MIXYE OPDXH
BPDBJ QBPYE BQBQX
OODHE A TIS ICHE SE OU HA D
THATW ITHOU TITI
BIVVI GBQMZ YRIUB C
TE E CTIS O E T

Replacement	D	F	G	H	I	kln	lno	P	Q					Y				M	B	E		J			
K2	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
Frequency		~~12~~	1	~~7~~	~~4~~		~~3~~	~~5~~	~~8~~	~~2~~			~~5~~		3	~~8~~	~~11~~	2		1	4	4	2	6	7	1

The **GYEVH** mapping to **COU?D** tells us that **V** must map to **L**:

QJQMP QGYEV HWDTI PQWEX HIUMB
DXHBP DBDVY RQXOO

IWISH ICOUL D A E HI U DE ST A
DTH ATALO I
YYHPI DUBQM UQGPI MIXYE OPDXH
BPDBJ QBPYE BQBQX
OODHE A TIS ICHE SE OU HA D
THATW ITHOU TITI
BIVVI GBQMZ YRIUB C
TELLE CTIS O E T

Replacement	D	F	G	H	I	kl	lo	P	Q			V			Y				M	B	E		J			
K2	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
Frequency		~~12~~	1	~~7~~	~~4~~		~~3~~	~~5~~	~~8~~	~~2~~			~~5~~		3	~~8~~	~~11~~	2		1	4	~~4~~	2	6	7	1

We can also immediately see that **W** and **X** must map to **M** and **N** in order to fit the alphabet in.
The **GYEVH** mapping to **COU?D** tells us that **V** must map to **L**:

QJQMP QGYEV HWDTI PQWEX HIUMB
DXHBP DBDVY RQXOO
IWISH ICOUL DMA E HIMUN DE ST A
DTH ATALO IN
YYHPI DUBQM UQGPI MIXYE OPDXH
BPDBJ QBPYE BQBQX
OODHE A TIS ICHE SENOU HAND
THATW ITHOU TITIN
BIVVI GBQMZ YRIUB C
TELLE CTIS O E T

Replacement	D	F	G	H	I	kln	lno	P	Q	rst	stu	V	W	X	Y				M	B	E		J			
K2	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
Frequency		~~12~~	1	~~7~~	~~4~~		~~3~~	~~5~~	~~8~~	~~2~~			~~5~~		3	~~8~~	~~11~~	2		1	4	~~4~~	~~2~~	~~6~~	~~7~~	1

That fills in quite a bit and we see **WDTI PQW EXHIUMNDXH** map to **MA?E HIM UNDE?STAND** which tells us that **T** must be **K**, and **U** must be **R**.

QJQMP QGYEV HWDTI PQWEX HIUMB
DXHBP DBDVY RQXOO
IWISH ICOUL DMAKE HIMUN DERST
ANDTH ATALO IN
YYHPI DUBQM UQGPI MIXYE OPDXH
BPDBJ QBPYE BQBQX
OODHE ARTIS RICHE SENOU HAND
THATW ITHOU TITIN
BIVVI GBQMZ YRIUB C

TELLE CTIS O ERT

Replacement	D	F	G	H	I	kln	lno	P	Q	rs	T	V	W	X	Y			U	M	B	E		J			
K2	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
Frequency		~~12~~	1	~~7~~	~~4~~		~~3~~	~~5~~	~~8~~	~~2~~			~~5~~		3	~~8~~	~~11~~	2		~~1~~	~~4~~	~~4~~	~~2~~	~~6~~	~~7~~	1

Looking at **IXYEOP** as **ENOU?H** means that **O** has to map to **G** (which is great as it is one of our candidates):

QJQMP QGYEV HWDTI PQWEX HIUMB
DXHBP DBDVY RQXOO
IWISH ICOUL DMAKE HIMUN DERST
ANDTH ATALO INGG
YYHPI DUBQM UQGPI MIXYE OPDXH
BPDBJ QBPYE BQBQX
OODHE ARTIS RICHE SENOU GHAND
THATW ITHOU TITIN
BIVVI GBQMZ YRIUB C
TELLE CTIS O ERT

Replacement	D	F	G	H	I	kln	O	P	Q	S	T	V	W	X	Y	Z		U	M	B	E		J			
K2	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
Frequency		~~12~~	1	~~7~~	~~4~~		~~3~~	~~5~~	~~8~~	~~2~~			~~5~~		~~3~~	~~8~~	~~11~~	2		~~1~~	~~4~~	~~4~~	~~2~~	~~6~~	~~7~~	~~1~~

We also know that **R** can't map to **J** because **VYRQX** would be **LOJING** which is not a word, so **S** must map to **J** (but it isn't used) and **R** must be in the keyword. We can't tell anything about the mapping to **F** since **K** and **L** aren't used at all. However, we can guess that **Z** must map to **P** because of where it fits in the alphabet and testing it at the one position near the end doesn't produce gibberish.

QJQMP QGYEV HWDTI PQWEX HIUMB
DXHBP DBDVY RQXOO
IWISH ICOUL DMAKE HIMUN DERST
ANDTH ATALO INGG
YYHPI DUBQM UQGPI MIXYE OPDXH
BPDBJ QBPYE BQBQX
OODHE ARTIS RICHE SENOU GHAND
THATW ITHOU TITIN
BIVVI GBQMZ YRIUB C
TELLE CTISP O ERT

Replacement	D	F	G	H	I	kln	O	P	Q	S	T	V	W	X	Y	Z		U	M	B	E		J			
K2	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
Frequency		~~12~~	1	~~7~~	~~4~~		~~3~~	~~5~~	~~8~~	~~2~~			~~5~~		~~3~~	~~8~~	~~11~~	2		~~1~~	~~4~~	~~4~~	~~2~~	~~6~~	~~7~~	1

We have only two more letter to map: **R** and **C**. They can only map to **Q V X Y** and **Z**. A quick look at **VYRQXO** mapping to **LO?ING** tells us that only **V** makes sense and we get:

QJQMP QGYEV HWDTI PQWEX HIUMB
DXHBP DBDVY RQXOO
IWISH ICOUL DMAKE HIMUN DERST
ANDTH ATALO VINGG
YYHPI DUBQM UQGPI MIXYE OPDXH
BPDBJ QBPYE BQBQX
OODHE ARTIS RICHE SENOU GHAND
THATW ITHOU TITIN
BIVVI GBQMZ YRIUB C
TELLE CTISP OVERT

Replacement	D	F	G	H	I	kln	O	P	Q	S	T	V	W	X	Y	Z		U	M	B	E	R	J			
K2	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
Frequency		~~12~~	1	~~7~~	~~4~~		~~3~~	~~5~~	~~8~~	~~2~~			~~5~~		~~3~~	~~8~~	~~11~~	~~2~~		~~1~~	~~4~~	~~4~~	~~2~~	~~6~~	~~7~~	~~1~~

At this point we only have one letter unmapped at the end. Since we are allowed to have up to two mistakes, we could simply go on to the next question and get full credit. But we should notice that we haven't figured out what the keyword is even though knowing that it existed was very helpful in solving the cipher. The letters we haven't mapped in the K2 alphabet are **A C K L N**. A quick bit of thinking testing the letters tells that either **N** or **L** should map to **Q**, but **LUMBERJ???** With **A C K** sitting there is just singing **LUMBERJACK** and we see that **C** maps to **Y** for the final answer of:

QJQMP QGYEV HWDTI PQWEX HIUMB
DXHBP DBDVY RQXOO
IWISH ICOUL DMAKE HIMUN DERST
ANDTH ATALO VINGG
YYHPI DUBQM UQGPI MIXYE OPDXH
BPDBJ QBPYE BQBQX
OODHE ARTIS RICHE SENOU GHAND
THATW ITHOU TITIN
BIVVI GBQMZ YRIUB C
TELLE CTISP OVERT Y

Replacement	D	F	G	H	I	N	O	P	Q	S	T	V	W	X	Y	Z	L	U	M	B	E	R	J	A	C	K
K2	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
Frequency		~~12~~	~~1~~	~~7~~	~~4~~		~~3~~	~~5~~	~~8~~	~~2~~			~~5~~		~~3~~	~~8~~	~~11~~	~~2~~		~~1~~	~~4~~	~~4~~	~~2~~	~~6~~	~~7~~	~~1~~

Breaking it up into words gives us the full original phrase:

I WISH I COULD MAKE HIM
UNDERSTAND THAT A LOVING GOOD
HEART IS RICHES ENOUGH AND THAT
WITHOUT IT INTELLECT IS POVERTY

7. Xenocrypt Div B Div C

Question #2 on 2018 Sample 9 is a Xenocrypt:

6) **[300 Points]** Solve this Xenocrypt which is a quote by Albert Einstein in Spanish.

MDJ FK FNFACKR IR FV KD CJQIUQCDK ADIFJD MF QIZKYQJ VRWJF KRV MFADV; FV KD YIQUD ADIFJD.

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

Here's one approach to solving it. Note that it is helpful to understand the most common words in Spanish. Wikipedia has a nice one at https://en.wikipedia.org/wiki/Most_common_words_in_Spanish with 100 words that are worth studying and recognizing.

1. Looking at the frequency, we see that both **D** and **F** are high frequency letters, so we will assume that they are ***E*** and ***A*** which are the most frequently used letters in Spanish. However, given that they are both the same, we must look at the usage. Looking at the two-letter words using them we see **FV KD**. Since there are almost no two letter words that start with ***A***, we can make a good guess that the **F** must be an ***E*** leaving **D** to stand for ***A***.

MDJ FK FNFACKR IR FV KD CJQIUQCDK ADIFJD MF QIZKYQJ
A E E E E A A A E A E
VRWJF KRV MFADV; FV KD YIQUD ADIFJD.
E E A E A A A E A

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

2. Taking another look at the **KD** the most obvious two-letter Spanish word is ***LA***, (the most common Spanish word), so we will guess that **K** stands for ***L***.

MDJ FK FNFACKR IR FV KD CJQIUQCDK ADIFJD MF QIZKYQJ
A EL E E L E LA AL A E A E L
VRWJF KRV MFADV; FV KD YIQUD ADIFJD.
E L E A E LA A A E A

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

3. The next two-letter word that is interesting is **FV**. The most common two-letter Spanish words are ***ES***, ***EL*** and ***EN***, but since we already have **K** standing for ***L***. We must choose between ***ES*** and ***EN***. Looking at the use of it right after the semi-colon, we can guess that it is **ES** since few sentences would start with ***EN***. We will assume that **V** stands for ***S***. Additional confirmation comes from looking at the **KRV** which would be ***L?S*** and must be ***LOS*** (since ***E*** and ***A*** are already known). This gives us that **R** stands for ***O***.

MDJ FK FNFACKR IR FV KD CJQIUQCDK ADIFJD MF QIZKYQJ
A EL E E LO O ES LA AL A E A E L
VRWJF KRV MFADV; FV KD YIQUD ADIFJD.
SO E LOS E AS ES LA A A E A

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

4. Our remaining high frequency letters are **I J** and **Q**. Given that the eight most common Spanish letters are ***EAOSNRIL*** and we have used five of them, we can check to see if ***NR*** and ***I*** make sense for filling in for any of them. Looking at the **IR** as ***?O***, we can only see ***NO*** as the two-letter word with **I** standing for ***N***. Looking at the first word **MDJ** as ***?A?***, there are no common words that end as ***?AI*** so we can guess that **J** stands for ***R***.

MDJ FK FNFACKR IR FV KD CJQIUQCDK ADIFJD MF QIZKYQJ
AR EL E E LO NO ES LA R N AL ANERA E N L R
VRWJF KRV MFADV; FV KD YIQUD ADIFJD.
SO RE LOS E AS ES LA N A ANERA

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

5. Another two-letter word stands out – **MF** as ***?E***. Another very common Spanish word is **DE** and since ***D*** has not been mapped, we will assume that **M** maps to ***D***. This works out well as it makes the first word be ***DAR***. Filling this in gives us:

MDJ FK FNFACKR IR FV KD CJQIUQCDK ADIFJD MF QIZKYQJ
DAR EL E E LO NO ES LA R N AL ANERA DE N L R
VRWJF KRV MFADV; FV KD YIQUD ADIFJD.
SO RE LOS DE AS ES LA N A ANERA

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

6. Coming back to the **Q** which we didn't map and remembering that we wanted to try ***I***, we look at usage and it fits nice with the last word on the first line, so we put it in to give us:

MDJ FK FNFACKR IR FV KD CJQIUQCDK ADIFJD MF QIZKYQJ
DAR EL E E LO NO ES LA RIN I AL ANERA DE IN L IR
VRWJF KRV MFADV; FV KD YIQUD ADIFJD.
SO RE LOS DE AS ES LA NI A ANERA

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

7. Looking at the ***?NI?A*** and the remaining letters, the only one which makes sense to be in front of the **N** is ***U*** so we will map **Y** to ***U***:

MDJ FK FNFACKR IR FV KD CJQIUQCDK ADIFJD MF QIZKYQJ
DAR EL E E LO NO ES LA RIN I AL ANERA DE IN LUIR
VRWJF KRV MFADV; FV KD YIQUD ADIFJD.
SO RE LOS DE AS ES LA UNI A ANERA

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

8. Looking at the ***?ANERA*** we look for letters which remain and could make sense as a word. We haven't used ***TCMPBHQYVGFJZÑXKW***. Going through the letters one at a time we have ***TANERA***, ***CANERA***, ***MANERA***, ***PANERA***, etc. But the only one which makes sense is ***MANERA***, so we map A to ***M*** to give us:

MDJ FK FNFACKR IR FV KD CJQIUQCDK ADIFJD MF QIZKYQJ
DAR EL E EM LO NO ES LA RIN I AL MANERA DE IN LUIR
VRWJF KRV MFADV; FV KD YIQUD ADIFJD.
SO RE LOS DEMAS ES LA UNI A MANERA

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

9. At this point, we have 8 letters that haven't been filled in. Since this is a 300-point question, you can get 7 letters wrong and still get 50 points, so every letter from here on out is worth 50 points. Looking at **CJQIUQCDK** as ***?RIN?I?AL*** we see that the **C** is used twice in that word. With our unused letter list now at ***TCPBHQYVGFJZÑXKW***, we quickly try them as ***TRIN?ITAL***, ***CRIN?ICAL***, ***PRIN?IPAL*** etc. and stop as we see that it looks suspiciously like ***PRINCIPAL*** and that it looks good paired in ***PRINCIPAL MANERA*** so we assume **C** maps to ***P*** and **U** maps to ***C*** which gives us 5 more letters solved:

MDJ FK FNFACKR IR FV KD CJQIUQCDK ADIFJD MF QIZKYQJ
DAR EL E EMPLO NO ES LA PRINCIPAL MANERA DE IN LUIR
VRWJF KRV MFADV; FV KD YIQUD ADIFJD.
SO RE LOS DEMAS ES LA UNICA MANERA

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

10. With only 3 letters unmatched, on this 300-point question, we would score 250 points, so we could stop. However, there is no penalty for guessing and any one of the three being right would get us 50 more points. Our remaining unused letters are ***TBHQYVGFJZÑXKW***; running letters through the three remaining words, possible guess are ***EJEMPLO*** and ***EXEMPLO***. Since ***J*** is more common than ***X***, we will guess **N** maps to ***J***. The only letter that makes sense for ***IN?LUIR*** is ***F*** (***C*** was already taken, otherwise we would guess ***INCLUIR***) so **Z** must map to ***F***. Lastly ***SO?RE*** is the very common Spanish word ***SOBRE*** so we map **W** to ***B*** with a solution of:

MDJ FK FNFACKR IR FV KD CJQIUQCDK ADIFJD MF QIZKYQJ
DAR EL EJEMPLO NO ES LA PRINCIPAL MANERA DE INFLUIR
VRWJF KRV MFADV; FV KD YIQUD ADIFJD.
SOBRE LOS DEMAS ES LA UNICA MANERA

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

DAR EL EJEMPLO NO ES LA PRINCIPAL MANERA DE INFLUIR SOBRE LOS DEMÁS; ES LA ÚNICA MANERA.

Translation: *Setting the example is not the main way to influence others; it's the only way*

8. Hill cipher 2x2 Div C

This utilizes matrix math in order to encode/decode groups of letters corresponding to the size of the matrix. For competition, you only need to worry about a 2x2 and 3x3 matrix. Note that if the message to encrypt is not a multiple of the size of the matrix, you add as many **Z**s to the remaining letter(s) to match the matrix size.

You can typically assume a normal mapping alphabet such as:

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	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

However, sometimes the alphabet is longer by adding punctuation and even digits. If that is the case, you just need to know the size of the alphabet and use that instead of the 26 for all the modulus operations.

To encrypt you start with a key matrix either 2x2 or 3x3. Typically, this is chosen by letters to make it easier to remember. However, you can't use any combination of letters, the determinant of the matrix must be coprime with the size of the alphabet. This means that if you are making up your own examples, you need to check that the matrix is invertible, or the message would not actually be decryptable.

8.a. 2x2 Encryption

For example, we will use a 2x2 matrix of the string **AXLE** which would be encoded as

$$\begin{pmatrix} A & X \\ L & E \end{pmatrix} = \begin{pmatrix} 0 & 2 \\ 11 & 4 \end{pmatrix}$$

If we wanted to encode **CIPHERS**, we need to break it into groups of 2 as **CI PH ER SZ** and do a matrix multiplication. Note the letter Z at the end to make it be a group of 2.

When you do the math in this case you get:

$$\begin{pmatrix} A & X \\ L & E \end{pmatrix}\begin{pmatrix} C \\ I \end{pmatrix} \equiv \begin{pmatrix} 0 & 23 \\ 11 & 4 \end{pmatrix}\begin{pmatrix} 2 \\ 8 \end{pmatrix} \equiv \begin{pmatrix} 0 \times 2 + 23 \times 8 \\ 11 \times 2 + 4 \times 8 \end{pmatrix} \equiv \begin{pmatrix} 184 \\ 54 \end{pmatrix} \equiv \begin{pmatrix} 2 \\ 2 \end{pmatrix} (mod\ 26) \equiv \begin{pmatrix} C \\ C \end{pmatrix}$$

$$\begin{pmatrix} A & X \\ L & E \end{pmatrix}\begin{pmatrix} P \\ H \end{pmatrix} \equiv \begin{pmatrix} 0 & 23 \\ 11 & 4 \end{pmatrix}\begin{pmatrix} 15 \\ 7 \end{pmatrix} \equiv \begin{pmatrix} 0 \times 15 + 23 \times 7 \\ 11 \times 15 + 4 \times 7 \end{pmatrix} \equiv \begin{pmatrix} 161 \\ 193 \end{pmatrix} \equiv \begin{pmatrix} 5 \\ 11 \end{pmatrix} (mod\ 26) \equiv \begin{pmatrix} F \\ L \end{pmatrix}$$

$$\begin{pmatrix} A & X \\ L & E \end{pmatrix}\begin{pmatrix} E \\ R \end{pmatrix} \equiv \begin{pmatrix} 0 & 23 \\ 11 & 4 \end{pmatrix}\begin{pmatrix} 4 \\ 17 \end{pmatrix} \equiv \begin{pmatrix} 0 \times 4 + 23 \times 17 \\ 11 \times 4 + 4 \times 17 \end{pmatrix} \equiv \begin{pmatrix} 391 \\ 112 \end{pmatrix} \equiv \begin{pmatrix} 1 \\ 8 \end{pmatrix} (mod\ 26) \equiv \begin{pmatrix} B \\ I \end{pmatrix}$$

$$\begin{pmatrix} A & X \\ L & E \end{pmatrix}\begin{pmatrix} S \\ Z \end{pmatrix} \equiv \begin{pmatrix} 0 & 23 \\ 11 & 4 \end{pmatrix}\begin{pmatrix} 18 \\ 25 \end{pmatrix} \equiv \begin{pmatrix} 0 \times 18 + 23 \times 25 \\ 11 \times 18 + 4 \times 25 \end{pmatrix} \equiv \begin{pmatrix} 575 \\ 298 \end{pmatrix} \equiv \begin{pmatrix} 3 \\ 12 \end{pmatrix} (mod\ 26) \equiv \begin{pmatrix} D \\ M \end{pmatrix}$$

Which gives us an encoded string of **CCFLBIDM.**

Now a common question is how to quickly do a mod `26` using a non-scientific calculator. The easiest way to do it is to take the number (for example `184`) and divide it by `26` to get `7.0769231`. You can subtract out the integer portion to get `0.0769231` and then multiply that by `26` to get `2.0000006` (remember that it may not have the same precision

as a scientific calculator), so we know that the remainder is 2 which corresponds to the letter **C**.

8.b. 2x2 Decryption

To decrypt you will need to determine the inversion of the 2x2 matrix. For a 2x2 there is a well-known solution:

$$A^{-1} \equiv \begin{bmatrix} a & b \\ c & d \end{bmatrix}^{-1} \equiv \frac{1}{\det(A)} \begin{bmatrix} d & -b \\ -c & a \end{bmatrix} \equiv \frac{1}{ad-bc} \begin{bmatrix} d & -b \\ -c & a \end{bmatrix}$$

To simplify matters, the det(A) is given as a table on the resources page. Since there are only 13 possible values for A you map them as follows.

1	3	5	7	9	11	15	17	19	21	23	25
1	9	21	15	3	19	7	23	11	5	17	25

9. Hill cipher 3x3 Div C

For a 3x3 matrix of the string **PRACTICED** which would be encoded as

$$\begin{pmatrix} P & R & A \\ C & T & I \\ C & E & D \end{pmatrix} \equiv \begin{pmatrix} 15 & 17 & 0 \\ 2 & 19 & 8 \\ 2 & 4 & 3 \end{pmatrix}$$

If we wanted to encode **SPECIALS**, we need to break it into groups of 3 as **SPE CIA LSZ** and do a matrix multiplication. In this case we get

$$\begin{pmatrix} P & R & A \\ C & T & I \\ C & E & D \end{pmatrix} \begin{pmatrix} S \\ P \\ E \end{pmatrix} \equiv \begin{pmatrix} 15 & 17 & 0 \\ 2 & 19 & 8 \\ 2 & 4 & 3 \end{pmatrix} \begin{pmatrix} 18 \\ 15 \\ 4 \end{pmatrix} \equiv \begin{pmatrix} 15 \times 18 + 17 \times 15 + 0 \times 4 \\ 2 \times 18 + 19 \times 15 + 8 \times 4 \\ 2 \times 18 + 4 \times 15 + 3 \times 4 \end{pmatrix} \equiv$$

$$\begin{pmatrix} 525 \\ 353 \\ 108 \end{pmatrix} \equiv \begin{pmatrix} 5 \\ 15 \\ 4 \end{pmatrix} (mod\ 26) \equiv \begin{pmatrix} F \\ P \\ E \end{pmatrix}$$

$$\begin{pmatrix} P & R & A \\ C & T & I \\ C & E & D \end{pmatrix} \begin{pmatrix} C \\ I \\ A \end{pmatrix} \equiv \begin{pmatrix} 15 & 17 & 0 \\ 2 & 19 & 8 \\ 2 & 4 & 3 \end{pmatrix} \begin{pmatrix} 2 \\ 8 \\ 0 \end{pmatrix} \equiv \begin{pmatrix} 15 \times 2 + 17 \times 8 + 0 \times 0 \\ 2 \times 2 + 19 \times 8 + 8 \times 0 \\ 2 \times 2 + 4 \times 8 + 3 \times 0 \end{pmatrix} \equiv$$

$$\begin{pmatrix} 166 \\ 156 \\ 36 \end{pmatrix} \equiv \begin{pmatrix} 10 \\ 0 \\ 10 \end{pmatrix} (mod\ 26) \equiv \begin{pmatrix} K \\ A \\ K \end{pmatrix}$$

$$\begin{pmatrix} P & R & A \\ C & T & I \\ C & E & D \end{pmatrix} \begin{pmatrix} L \\ S \\ Z \end{pmatrix} \equiv \begin{pmatrix} 15 & 17 & 0 \\ 2 & 19 & 8 \\ 2 & 4 & 3 \end{pmatrix} \begin{pmatrix} 11 \\ 18 \\ 25 \end{pmatrix} \equiv \begin{pmatrix} 15 \times 11 + 17 \times 18 + 0 \times 25 \\ 2 \times 11 + 19 \times 18 + 8 \times 25 \\ 2 \times 11 + 4 \times 18 + 3 \times 25 \end{pmatrix} \equiv$$

$$\begin{pmatrix} 471 \\ 564 \\ 169 \end{pmatrix} \equiv \begin{pmatrix} 3 \\ 18 \\ 13 \end{pmatrix} (mod\ 26) \equiv \begin{pmatrix} D \\ S \\ N \end{pmatrix}$$

Which gives us an encoded string of **FPEKAKDSN.**

Decoding is done in the same manner, but the 3x3 decoding matrix will be provided. In this case we can decode the string **FPEKAKDSN** which was encoded using the string **PRACTICED** for which we will get the inverse matrix:

$$\begin{pmatrix} P & R & A \\ C & T & I \\ C & E & D \end{pmatrix}^{-1} \equiv \begin{pmatrix} 15 & 17 & 0 \\ 2 & 19 & 8 \\ 2 & 4 & 3 \end{pmatrix}^{-1} \equiv \begin{pmatrix} 1 & 25 & 20 \\ 16 & 7 & 16 \\ 4 & 0 & 9 \end{pmatrix}$$

Using this matrix, we proceed the same way as encoding breaking up in groups of 3 and do the matrix multiplications

$$\begin{pmatrix}1 & 25 & 20\\16 & 7 & 16\\4 & 0 & 9\end{pmatrix}\begin{pmatrix}F\\P\\E\end{pmatrix} \equiv \begin{pmatrix}1 & 25 & 20\\16 & 7 & 16\\4 & 0 & 9\end{pmatrix}\begin{pmatrix}5\\15\\4\end{pmatrix} \equiv \begin{pmatrix}1\times 5+25\times 15+20\times 4\\16\times 5+7\times 15+16\times 4\\4\times 5+0\times 15+9\times 4\end{pmatrix} \equiv \begin{pmatrix}460\\249\\56\end{pmatrix} \equiv \begin{pmatrix}18\\15\\4\end{pmatrix} (mod\ 26) \equiv \begin{pmatrix}S\\P\\E\end{pmatrix}$$

$$\begin{pmatrix}1 & 25 & 20\\16 & 7 & 16\\4 & 0 & 9\end{pmatrix}\begin{pmatrix}K\\A\\K\end{pmatrix} \equiv \begin{pmatrix}1 & 25 & 20\\16 & 7 & 16\\4 & 0 & 9\end{pmatrix}\begin{pmatrix}10\\0\\10\end{pmatrix} \equiv \begin{pmatrix}1\times 10+25\times 0+20\times 10\\16\times 10+7\times 0+16\times 10\\4\times 10+0\times 0+9\times 10\end{pmatrix} \equiv \begin{pmatrix}210\\320\\130\end{pmatrix} \equiv \begin{pmatrix}2\\8\\0\end{pmatrix} (mod\ 26) \equiv \begin{pmatrix}C\\I\\A\end{pmatrix}$$

$$\begin{pmatrix}1 & 25 & 20\\16 & 7 & 16\\4 & 0 & 9\end{pmatrix}\begin{pmatrix}D\\S\\N\end{pmatrix} \equiv \begin{pmatrix}1 & 25 & 20\\16 & 7 & 16\\4 & 0 & 9\end{pmatrix}\begin{pmatrix}3\\18\\13\end{pmatrix} \equiv \begin{pmatrix}1\times 3+25\times 18+20\times 13\\16\times 3+7\times 18+16\times 13\\4\times 3+0\times 18+9\times 13\end{pmatrix} \equiv \begin{pmatrix}713\\382\\129\end{pmatrix} \equiv \begin{pmatrix}11\\18\\25\end{pmatrix} (mod\ 26) \equiv \begin{pmatrix}L\\S\\Z\end{pmatrix}$$

Which gives us an encoded string of **SPECIALSZ**. Since we know that the **Z** at the end is padding, our answer is **SPECIALS**.

10. Affine cipher Div B

The Affine cipher is a simple substitution cipher where each letter maps to exactly one other letter.

Given an alphabet of size *m*, you need to have two key values *a* and *b* such that *a* and *m* are coprime (i.e., there is no positive divisor for both other than 1). If *a=1,* then the Affine cipher is a trivial Caesar cipher. Assuming *m=26* as, you will find most commonly, then the possible values for a will be 1, 3, 5, 7, 9, 11 ,15, 17, 19, 21, 23 and 25.

10.a. Encryption

To encrypt a letter, the formula is

E(x) = (ax + b) mod m

Assuming a normal alphabet such as:

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	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

We can pick a value of *a=7* and *b=42*.

Plaintext	S	C	I	E	N	C	E	O	L	Y	M	P	I	A	D
x	18	2	8	4	13	2	4	14	11	24	12	15	8	0	3
(7x+42)	168	56	98	70	133	56	70	140	119	210	126	147	98	42	63
(7x+42) mod 26	12	4	20	18	3	4	18	10	15	2	22	17	20	16	11
ciphertext	M	E	U	S	D	E	S	K	P	C	W	R	U	Q	L

10.b. Decryption by Formula (hard)

If you had a message and were given the values of *a* and *b*, you must apply a formula to build the decryption for each letter. The formula is

D(x) = a-1 (x - b) mod m

where a^{-1} is the modular multiplicative inverse of *a* mod *m*.

1 = aa-1 mod m

If we want to decrypt it, we must figure out multiplicative inverse of *a* mod *m*. There are some approximation ways to do it, but since there are

only 26 values, we can brute force it to look for the one value of t where the result of $t*a \bmod m = 1$.

t	1	2	3	4	5	6	7	8	9	10	11	12	13
$t*7 \bmod 26$	7	14	21	2	9	16	23	4	11	18	25	6	13

T	14	15	16	17	18	19	20	21	22	23	24	25	26
$t*7 \bmod 26$	20	1	8	15	22	3	10	17	24	5	12	19	0

Based on this, we know that $a^{-1} = 15$ and we can proceed to decrypt.

ciphertext	M	E	U	S	D	E	S	K	P	C	W	R	U	Q	L
y	12	4	20	18	3	4	18	10	15	2	22	17	20	16	11
15(y - 42)	-450	-570	-330	-360	-585	-570	-360	-480	-405	-600	-300	-375	-330	-390	-465
15(y - 42) mod 26	18	2	8	4	13	2	4	14	11	24	12	15	8	0	3
Plaintext	S	C	I	E	N	C	E	O	L	Y	M	P	I	A	D

While this is possible to do, it requires a bit of trial and error to figure out the multiplicative inverse. As such, there are easier ways you could approach decryption if you do know some characters:

10.c. Decryption when you know some characters (Easier)

Sometimes you will be given the ciphertext and a couple of plain text letters. For example.

Suppose you were given the ciphertext of

GLIID MGNF NF J XNKGLY

and are told that the first word is `HELLO`.

You can start out by figuring out what the values of a and b are as follows:

We know that the characters map like this:

```
H(7)    =>  G(7)
E(4)    =>  L(11)
L(11)   =>  I(8)
L(11)   =>  I(8)
O(14)   =>  D(3)
```

To determine the values of a and b from the formula:

`Output =` $ax+b$ `(mod 26)`

You only need to have two letters mapped. For convenience, we just pick the first two, write them as the formula and then solve for b initially: So, we have:

$$a * 7 + b\ (Mod\ 26) = 6$$
$$a * 4 + b\ (Mod\ 26) = 11$$

You can cancel out the a in both by multiplying each by the other a value. I.e., since the first is a*7, and then second is a*4 we multiply the first by 4 and the second by 7

$$4 * (a * 7 + b\ (Mod\ 26)) = 4 * 6$$
$$7 * (a * 4 + b\ (Mod\ 26)) = 7 * 11$$

Simplify them to get:

$$a * 28 + 4 * b\ (Mod\ 26) = 24$$
$$a * 28 + 7 * b\ (Mod\ 26) = 77$$

Don't worry about the mod 26 portion for now, we will handle it in a bit. Next, we need to subtract to cancel out the a. For convenience, subtract the smaller from the larger:

$$a * 28 + 7 * b\ (Mod\ 26) = 77$$
$$\underline{-\ a * 28 + 4 * b\ (Mod\ 26) = 24}$$
$$3 * b\ (Mod\ 26) = 53$$

Since the modulus is a one-way transformation, we need to take the mod of the right-hand side which is 1. So, we know that:

$$3 * b\ (Mod\ 26) = 1\ (or\ some\ other\ mod\ 26\ value)$$

To discover which value of b there is, simply compute the other modulus values and see which is a perfect multiple. We know it can't be 1 since b must be an integer.

Add `26` to get `27` and we observe that `27/3 = 9`

So, we now know that b=`9`. Now we need to solve for a. All we need to do is substitute 9 in for b in either of the formulas and repeat the same process again. For convenience we use the second formula since it is easier to see if something is a power of 4 vs. a power of 7

$$a * 4 + 9\ (Mod\ 26) = 11$$
$$a * 4 + 9 - 9\ (Mod\ 26) = 11 - 9$$
$$a * 4\ (mod\ 26) = 2$$

Just like before we look for a modulus value which is a perfect multiple of `4`. We know that it isn't `2`, so we add `26` to `2` to get `28`. Since `28/4 = 7` we know that a=`7`.

Now that you know that b=`9` and a=`7`, you need to decode the remainder of the text.

G	L	I	I	D		M	G	N	F		N	F		J		X	N	K	G	L	Y
H	E	L	L	O															H	E	

Starting with the most frequent characters, calculate the mappings for ETAOIN. However, take note that the letter A is 0 which means that all you need to do is look up the value of b in the table to know the output letter.

Unencrypted	Value	7*x+9	7*x+9 mod 26	Encrypted
E	4	We already knew this		**L**
T	19	142	12	**M**
A	0	Don't bother to calculate, just look *b* up		**J**
O	14	We already knew this		**D**
I	8	65	13	**N**
N	13	100	22	**W**

With the 4 new letters we can fill in the cipher as follows.

G	L	I	I	D		M	G	N	F		N	F		J		X	N	K	G	L	Y
H	E	L	L	O		T		I			I			A			I		H	E	

A quick look at what was decoded so far suggests that it says something like **HELLO THIS IS A** so you can confirm it by encoding the letters **H** and **S** to confirm.

Unencrypted	Value	7*x+9	7*x+9 mod 26	Encrypted
H	7	58	6	**G**
S	18	135	5	**F**

That confirms the guess, so we fill them in.

G	L	I	I	D		M	G	N	F		N	F		J		X	N	K	G	L	Y
H	E	L	L	O		T	H	I	S		I	S		A			I		H	E	

Looking at the next most frequent characters, we have **R L** and **D**, so we calculate them.

Unencrypted	Value	7*x+9	7*x+9 mod 26	Encrypted
R	17	128	24	**Y**
L	11	86	8	**I**
D	3	30	4	**E**

Only one of those letters are in the key giving us:

G	L	I	I	D		M	G	N	F		N	F		J		X	N	K	G	L	Y
H	E	L	L	O		T	H	I	S		I	S		A			I		H	E	R

As this point you have gotten all but two of the letters. By the current rules, this would count as a correct solution with two letters wrong and you could leave it and go on, or you could guess some more or continue down the list of the frequency table. For now, it looks like those last two letters might be a **C** and **P** respectively, so we can test that quickly.

Unencrypted	Value	7*x+9	7*x+9 mod 26	Encrypted
C	2	23	23	**X**
P	15	114	10	**K**

Which confirms our guess giving us a final solution of:

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

11. Vigenère cipher Div A

A Vigenère cipher uses a repeating key in order to apply a different Caesar cipher to each letter in the group. The typical mapping table looks like this.

	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	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

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

To encrypt any phrase, you need to first pick a code key.
Then you repeat the code phrase as many times as necessary to cover the entire plaintext that you wish to encode. Note that for any characters what aren't encoded (like spaces and punctuation marks) you pretend that they aren't there and just use the next code phrase character with the next character to encode.

Plaintext: **SCIENCE OLYMPIAD CODE BREAKERS**
Key: *CEASER***C EASERCEA SERC EASERCEA**
Ciphertext: **UGIWRTG SLQQGKED USUG FRWEBGVS**

To encode, all you need to do is take the character from the plaintext and the corresponding character from the key and look them up in the column and row of the mapping table. In this example for the first character, you have a Plaintext of **S** and a Key of **C**. Look in the **S** row and the **C** column to find the letter **U**. Note you can use the **S** column and the **C** row and you will get the same result. You repeat this process for each of the letters in the Plaintext.
To decrypt, you need to do the reverse, BUT instead of using the letters as the row and column header, you use the corresponding key to find the row or column and then find the corresponding ciphertext character in that column (or row) and use the matching header as the decryption key. So, in this case with a Ciphertext of **U** and a key of **C** you go to the column labeled **C** and look down

until you find the letter **U** and then find the corresponding row header to see that it is the letter **S**.

12. Porta cipher Div B Div C

A Porta cipher works very much like the Vigenère cipher uses a repeating key in order to apply a different mapping to each letter in the group. The biggest difference is that it uses a different mapping and that there are only 13 different possibilities. Note that there are other options for the Porta table, but we are using the ACA convention for the table (https://www.cryptogram.org/downloads/aca.info/ciphers/Porta.pdf).

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

One significant attribute of the Porta cipher is that letters in the A–M range will map to a letter in the N–Z range and vice-versa. In many ways, this makes the cipher easier to break with only a few clues.

Plaintext: **SCIENCE OLYMPIAD CODE BREAKERS**
Key: *PORTA***PO RTAPORTA PORT APORTAPO**
Ciphertext: **LWQNAWY GULTIQWQ WHYN OKYVTRKL**

Another interesting attribute of the Porta cipher is that it is 100% reversable. Encrypting the Ciphertext with the same key results in the Plaintext.

To decrypt, you take the letter from the key and use it to determine the row in the porta table. Then you look at the corresponding letter to encode/decode. If the letter is in the A–M range, you use the row at the top to determine the column and pull the corresponding letter out of the selected row. If the letter is in the N–Z range, you find the column in the selected row and then look at the top to find the corresponding character.

For example, with the first two letters, we take the P as the key and L as the Cipher text character. We look at the next to the last column which starts with the L and then go down to the O, P row to see the letter S. For the second letter, we have O as the key and W as the Cipher text character. We look in the same O, P row and scan over until we see the letter W in the third data column. We look to the header cell at the top and see that the letter C as the decoded character.

12.a. Cryptanalysis of a Porta Cipher

The following quote has been encoded with the Porta Cipher using a very common four letter word for the key. The 30th through 33rd cipher characters (**YVIH**) decode to be **EANS**

HHUWI PUWHE GCUAK BSUAW IHOCP LKBSY VIHCZ M

We start by first filling in what has been given to us as the clue.

HHUWI PUWHE GCUAK BSUAW IHOCP LKBSY VIHCZ M

E

ANS

Using the porta table, we need to determine what the key characters are. We start with the cipher text **Y** which decodes to be **E**. Since **E** is in the A–M range, we look for the E column in the table and the scan down until we find the **Y**. From there we look at the row header and find that it corresponds to **O,P** so we will put an **O** above the **Y** as the keyword since both **O** and **P** decode to the same thing.

O

QKW
HHUWI PUWHE GCUAK BSUAW IHOCP LKBSY VIHCZ M

E

ANS

We repeat this process. Next, looking in the **A** column for a **V** we find that it corresponds to **Q,R**. When we get to the Cipher text **I** decoding to **N** we have to change our strategy of lookup because **N** is in the N–Z range. Instead of looking in the **N** column (which doesn't exist in the table) for an **I**, we look in the **I** column for an **N** and find it in the **K,L** row. This is an important attribute of the Porta Cipher being reversable. You will always notice that any character that is in the A–M range will map to something in the N–Z range. This means when looking up the letters, you need to pay attention to which is in a and use it for the column and then find the other value (which will be N–Z) to determine the correct row. As such it is often easier to think about the cipher character and the plaintext character as a pair and always order it alphabetically. This way it becomes faster to look them up. We can look up the last **H/S** pair to come up with the **W,X** row by finding the **S** in the **H** column. This gives us the following:

O

QKW

HHUWI PUWHE GCUAK BSUAW IHOCP LKBSY VIHCZ M

E

ANS

We now have a couple of options. Since we are told that the key is a four letter word, we could try to figure out what it is by counting to find out where the word split would start. Since it starts at the 30th character, we do a quick 30 mod 4 of it to find out that the O would be the second character. This means that the W would be the first character because the keyword repeats. Putting them in order and including the alternates in the pairs (**W,XO,PQ,RK,L**) it doesn't take a rocket scientist to see that the four letter word must be **WORK**.

WOQK

XPRL

With that in mind we can just start from the beginning and fill in the keyword

WORKW ORKWO RKWOR KWORK WORKW ORKWO RKWOR K

HHUWI PUWHE GCUAK BSUAW IHOCP LKBSY VIHCZ M

E

ANS

This technique works really well when you aren't given enough letters for the keyword, for example, if it was a 5 letter keyword and we were only given four clue letters. But if you are told how many letters were in the keyword, you can simply ignore figuring out the keyword and just start filling in forwards and backwards.

So if we didn't try to figure out the keyword, but we have four of the four letters, we just put the **W** in front of the **O** over the **S**, the **K** before that, **Q** and so on repeating until we get to the start.

WOQKW OQKWO QKWOQ KWOQK WOQKW OQKWO QKW

HHUWI PUWHE GCUAK BSUAW IHOCP LKBSY VIHCZ M

E

ANS

Then you also fill in from the **W** on to the end

WOQKW OQKWO QKWOQ KWOQK WOQKW OQKWO QKWOQ K

HHUWI PUWHE GCUAK BSUAW IHOCP LKBSY VIHCZ M

E

ANS

Next comes decoding the ciphers. With the keyword, you can go much faster as you have the row to work from. The easiest way to do this is to attack all of the cipher characters which use the same encoding letter. We can start with the **W** and look at the row of the table to make it easy for us.

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

With this in mind, we find all of the ones under a **W** and map them. The H column header has an **S** in the **W,X** row. **I** gets us a **T**. Another **H** maps again to **S**. When we get to the **U**, we have to do the reverse and find the column it is in giving us a **J**. When we see the **S**, we remember that **H** mapped to **S** earlier, so we do the reverse. Another **I** gives us the **T** again. For the **P** we have to find the column header for the **P** in the **W,X** row which is **E**. Another **S** is an **H** and we end up with:

WOQKW OQKWO QKWOQ KWOQK WOQKW OQKWO QKWOQ K

HHUWI PUWHE GCUAK BSUAW IHOCP LKBSY VIHCZ M

S T S J H T E HE

ANS

Now that one letter is done, we proceed to the O row which is

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

We follow the same strategy. This time the **H** column maps to **O**. We find the **P** in the **I** column. **E** maps to **Y**. The **A** column gives us **U**, and the fortunate next **U** is the reverse giving us an **A**. Another **H** maps to **O**. **S** is in the **L** column, and the last **C** column gives us **W**

WOQKW OQKWO QKWOQ KWOQK WOQKW OQKWO QKWOQ K

HHUWI PUWHE GCUAK BSUAW IHOCP LKBSY VIHCZ M

SO T I SY JU HA TO E S HE ANSW

Looking at what we have so far, a couple of words are obvious at the end so we fill them in.

WOQKW OQKWO QKWOQ KWOQK WOQKW OQKWO QKWOQ K

HHUWI PUWHE GCUAK BSUAW IHOCP LKBSY VIHCZ M
SO T I SY JU HA TO E S THE ANSWE R

We still have more to solve, so next we take the **Q,R** row

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

Looking up **U** finds it in **M** column and the next one is exactly the same – you should be able to see the benefit of doing all one row at a time now. The **G** column gives us **O**, followed by the **K** column that gives us **S**. Continuing on, the **A** column gives us **V**, and since we know **G** gave us **O**, we just enter **O** for **G** to find another **K** that we already mapped to **S**. This gives us a mostly complete one at:

WOQKW OQKWO QKWOQ KWOQK WOQKW OQKWO QKWOQ K
HHUWI PUWHE GCUAK BSUAW IHOCP LKBSY VIHCZ M
SOM T IM SY O JUS HAV TOG E S THE ANSWE R

At this point, some of the letters are obvious. It must start out as **SOMETIMES** and the **JUS? HAV?** Must be **JUST HAVE**. That only leaves the **C** mapped by the **K,L** row which we can either leave blank (don't forget the up to two wrong rule) or look it up and see that it is a **U**.

WOQKW OQKWO QKWOQ KWOQK WOQKW OQKWO QKWOQ K
HHUWI PUWHE GCUAK BSUAW IHOCP LKBSY VIHCZ M
SOMET IMESY O JUS THAVE TOGUE SSTHE ANSWE R

Now that everything is done, you can see that the cipher decoded to be:

SOMETIMES YOU JUST HAVE TO GUESS THE ANSWER

13. Baconian Div B Div C

13.a. General Baconian strategies

There are two forms of a Baconian: 24 and 26 character. Science Olympiad uses the 24-character form, and the corresponding Baconian table will be provided as a resource for the test and looks like this:

AAAAA	A
AAAAB	B
AAABA	C
AAABB	D
AABAA	E
AABAB	F

AABBA	G
AABBB	H
ABAAA	I/J
ABAAB	K
ABABA	L
ABABB	M

ABBAA	N
ABBAB	O
ABBBA	P
ABBBB	Q
BAAAA	R
BAAAB	S

BAABA	T
BAABB	U/V
BABAA	W
BABAB	X
BABBA	Y
BABBB	Z

1. The first step is to identify the type of Baconian.

- A letter for letter will generally have a random set of patterns such as:

^^^^ ^^^^^^^^ ^^ ^ ^ ^^^ ^^^^^^^^^ ^^

- A Pattern Baconian will have a general repeating set of symbols like:

HellŏHelloHelḷoHĕḷlŏHĕḷloHĕlloHelloHĕḷlo

- A Word Baconian will have a semi-readable sentence like:

I SAID GO SAY A SONG UNTIL ONLY A SNAKE WAKES UP TOO

2. Break the pattern into groups of 5. One thing to be aware of is that a Baconian cipher may have nulls. An example of this is:

WHĘŃ IŊ ŢHÉ CÓÚRŞÉ ÓF HÚMĄŃ ĘVÉŃŢŚ IŢ BÉCÓMÉŚ

In this case, only the characters with accents are part of the Baconian alphabet.

3. For the first two types, you need to identify what corresponds to an **A** or a **B**. A key factor to remember for all Baconian ciphers is that if you look at the table, no Baconian letter starts with **BB**. As such in any group of 5 if the first two letters are the same, you know that they must stand for an **A**.

4. Another way to identify which is **A** and which is **B** is to count the number of each type. The **A**'s will greatly outnumber the **B**'s

5. Also, a sequence of 5 characters all the same must be composed of all **A** characters and correspond to the plain text letter A.

13.b. Letter for Letter Baconian

Counting is your best friend here. If you can identify two different types of symbols, then you will be able to pick what is A and what is B. Sometimes it is a bit complicated. For example, the 2018 NC State test had a Baconian like:

↑↓↖↘↘↓↘↑↓↓↘↓↑↘↘↓↘↓↓↘↓↓↘↖↘↓↘↑↑↖↘↓↑↘↘↑↘↖↓↖↓↑↘↘↘↖↘↘↓↖

This contains several obvious options to consider here:

1. Up vs down: ↑↑↖↖ ↓↓↘↘
2. Straight vs Angled: ↑↑↓↓ ↖↖↘↘
3. Line vs No Line: ↑↓↖↘ ↑↓↖↘

The first step is to break it into groups of 5

↑↓↖↘↘ ↓↘↑↓↓ ↘↓↑↘↘ ↓↘↓↓↘ ↓↓↘↖↘ ↓↘↑↑↖ ↘↓↑↘↘ ↑↘↖↓↖ ↓↑↘↘↘ ↖↘↘↓↖

Next for the groups of 5 take a small set and identify the type of character. Since we have three possibilities, we should write the options down to distinguish them:

ududd ddudd ddudd ddddd dddud dduuu ddudd ududu duddd udddu

ssaaa sasss assaa sassa ssaaa sassa assaa saasa ssaaa aaasa

nlnnl nnlln nlnnl nnlnn nlnll nnlnn nlnnl lnnnl nnnnl nnnln

Looking at the second set, we see groups that start bout as **ss** and **aa** which means we can immediately reject that option without any further looking.

For the second set we see that the second word starts with **dd** which would mean **d=A**. A quick lookup of the first few letters:

ududd ddudd ddudd ddddd dddud

babaa aabaa aabaa aaaaa aaaba

W E E A C

Comes out as **WEEAC** which seems productive, so we quickly try the last choice. Since we see a group that starts out as **nn**, we must conclude that **n=A** and quickly try out the first few letters to discover that they come out as gibberish with **KGK**.

nlnnl nnlln nlnnl

abaab aabba abaab

K G K

13.c. Pattern Baconian

Pattern Baconian ciphers are attacked in the same manner as for the Letter for Letter Baconian. For example, if we had:

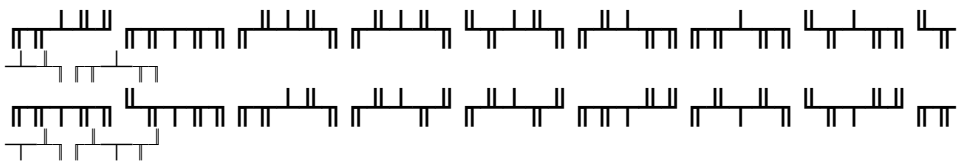
ǏTS CǑĹD OǓTSIDE IǏS ČǑLĎ OǓTSIDE ITŠ COLD OǓTŜǏDE ITS CǑĹD OUTSǏĎE ǏǏŠ CǑLD OUTSIDE ITS ČOĹD OǓTSǏDE ITS CǑLD OǓTSIDE ǏTS ČOLD OǓǏŜIDE ǏǏŠ COĹD OǓTSIDĚ ITS Č

It is quite apparent that the accented vs non-accented characters indicate the difference. A quick counting shows that only 10 out of the first 31 characters are accented which gives up accent=**B**. Applying this logic and breaking up into groups of 5 we get which starts out to decode as **STAY WARM**.

BAAAB BAABA AAAAA BABBA BABAA AAAAA BAAAA ABABB

S T A Y W A R M

Another style may be symbols such as were encoded in a tweet. Fortunately, in this case they are grouped into sets of 5. A quick look at the group shows the second group where all the lines are pointing down. Furthermore, counting them shows that 20 out of the first 35 characters are point down which is a strong indication that the down lines=**A** and up lines =**B**.



Applying that logic, the first 5 groups come out as:

aabbb aaaaa abbba abbba babba
H A P P Y

13.d. Word Baconian

The strategy for attacking a Word Baconian is slightly different. There will be multiple letters which map to **A** and **B**. For example, given the sample below with a hint that it starts out as **EVER**:

Maria built movie house badly.
Super quick clock wrong.
Board loose since chase begun
Music buyer being movie extra.
Heavy urban tower built worse since Maria began visit.

The first step is to map the letters that we know.

Maria built movie house
AABAA BAABB AABAA BAAAA
E V E R

With that, we build a table showing what the letters all map to

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	B			A			B	A			B	A		A			B	A	B	A					

Looking at the table, we see that it starts out as **AB** and under **RSTU** we have a run of **BABA**. The most logical pattern in this case would just be alternating **A** and **B** mappings. A quick check of the next word **badly** maps it as **BA?B?** and if our guess is right, it is **BABBA** which maps to **Y** making our phrase start out as **EVERY**. Filling in the rest of the table gives us:

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	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B

which we can use to decode the reminder of the phrase.

Note that it is very unlikely that the pattern will be as simple as **ABAB**… but it is reasonable to expect a pattern. Some additional techniques that you can use:

1. Even if there weren't a pattern (or you can't figure out the pattern), you can fill in the table by looking for groups of 5 that you know 4 of the mappings and identifying the possible letter choices which make sense in the decrypted text.
2. If you know one of the first two letters in a group are a **B**, (i.e., it starts out as **B?** or **?B**) then you can guarantee that the other letter maps to an **A**.

14. Morbit

The Morbit cipher uses Morse Code to encode the text.

There will be a Morse code table in forward and reverse on the resources page:

A	●–	**F**	●●–●	**K**	–●–	**P**	●––●	**U**	●●–
B	–●●●	**G**	––●	**L**	●–●●	**Q**	––●–	**V**	●●●–

C	−●−●
D	−●●
E	●

H	●●●●
I	●●
J	●−−−

M	−−
N	−●
O	−−−

R	●−●
S	●●●
T	−

W	●−−
X	−●●−
Y	−●−−
Z	−−●●

0	−−−−−
1	●−−−−

2	●●−−−
3	●●●−−

4	●●●●−
5	●●●●●

6	−●●●●
7	−−●●●

8	−−−●●
9	−−−−●

●	E
●●	I
●●●	S
●●●●	H
−●●●	B
−−−−−	0
●●●●●	5

−	T
●−	A
●●−	U
●●●−	V
−●●−	X
●−−−−	1
−●●●●	6

−●	N
●−●	R
●●−●	F
−●−●	C
●●−−−	2
−−●●●	7

−−	M
●−−	W
●−●●	L
−●−−	Y
●●●−−	3
−−−●●	8

−●●	D
●−−●	P
−−●●	Z
●●●●−	4
−−−−●	9

−●−	K
●−−−	J
−−●−	Q

−−●	G

−−−	O

14.a. A Morbit problem to solve

For example, given the following cipher text to decode of and being told that it starts out as **CODE**:

99232572585158186858

The first thing to do is to map out what **CODE** would be in Morse code. Note that we use X to represent spaces.

-.-.X---X-..X.X

Next, we split it up into groups of 2 and map it to the cipher text

```
-. -. X- -- X- .. X. X-
9  9  2  3  2  5  7  2
```

We then build a table of mapping for what we know:

```
1   2   3   4   5   6   7   8   9
??  X-  --  ??  ..  ??  X.  ??  -.
```

Based on the crib, we know the mapping of 5 of the 9 characters and are left looking for **.-**, **.X**, **-X** and **XX.**

```
9  9  2  3  2  5  7  2  5  8  5  1  5  8  1  8  6
8  5  8
-. -. X- -- X- .. X. X- .. ?? .. ?? .. ?? ?? ??
?? ?? .. ??
C       O      D      E
```

Looking at the next letter in the sequence, we know that it starts out as -.. and that 8 must have an X in it (otherwise you would have at least 7 characters in a row without an X. Since we only have -X and XX left we can try them both.

First with 8=**-X** we get

```
9  9  2  3  2  5  7  2  5  8  5  1  5  8  1  8  6
8  5  8
-. -. X- -- X- .. X. X- .. -X .. ?? .. -X ?? -X
?? -X .. -X
C     O     D     E  X        ?     ?     ?     ?
U
```

Which doesn't seem likely, particularly with the U at the end

With 8=**.X** we get

```
9  9  2  3  2  5  7  2  5  8  5  1  5  8  1  8  6
8  5  8
-. -. X- -- X- .. X. X- .. .X .. ?? .. .X ?? .X
?? .X .. .X
C     O     D     E  B        ?     ?     ?     ?
S
```

Which looks promising and tells us that 1 must be either the remaining **-X** or **XX**, so we try **-X**

```
9  9  2  3  2  5  7  2  5  8  5  1  5  8  1  8  6
8  5  8
-. -. X- -- X- .. X. X- .. .X .. -X .. .X -X .X
?? .X .. .X
C     O     D     E  B        U     S     T  E  ?
S
```

Based on this, the only logical choice for 6 is to be **.-** which gives us

```
9  9  2  3  2  5  7  2  5  8  5  1  5  8  1  8  6
8  5  8
-. -. X- -- X- .. X. X- .. .X .. -X .. .X -X .X
.- .X .. .X
C     O     D     E  B        U     S     T  E  R
S
```

Which means our table ends up as below (4 wasn't used and **XX** was left over so we get to put that in).

```
1   2   3   4   5   6   7   8   9
-X  X-  --  XX  ..  .-  X.  .X  -.
```

15. Pollux

A Pollux cipher is like a Morbit cipher, using the same Morse Table which should be on the resources page:

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	−−−−−
1	●−−−−

2	●●−−−
3	●●●−−

4	●●●●−
5	●●●●●

6	−●●●●
7	−−●●●

8	−−−●●
9	−−−−●

●	E
●●	I
●●●	S
●●●●	H
−●●●	B
−−−−−	0
●●●●●	5

−	T
●−	A
●●−	U
●●●−	V
−●●−	X
●−−−−	1
−●●●●	6

−●	N
●−●	R
●●−●	F
−●−●	C
●●−−−	2
−−●●●	7

−−	M
●−−	W
●−●●	L
−●−−	Y
●●●−−	3
−−−●●	8

−●●	D
●−−●	P
−−●●	Z
●●●●−	4
−−−−●	9

−●−	K
●−−−	J
−−●−	Q

−−●	G

−−−	O

15.a. A Pollux problem to solve

Someone has encoded a phrase using the Pollux cipher and told you that 2,3 are Dots, 5,6 are Dashes and 8,9 are spaces (x). What does it say?

120598110122784733744918059466981433939350262961983130455866718756946591628223037761517666963203

15.b. Background on Solving Pollux

The Pollux cipher works by first converting the text into Morse code which is written as a series of dots (●), dashes (–), and spaces. To make it more convenient to solve, we typically represent the spaces as an ×. A single space is used at the end of a Morse code letter and a pair of spaces is used at the end of a word.

The person encoding the text then decides with digits will stand for dots/dashes/spaces with no restriction on that choice. For example, all the spaces could be represented by a 2, all of the dots by a 1 and all the other digits stand for a dash. Given the mapping of the digits, the Morse code is translated to the cipher text by picking a digit for the dash/dot/space. Since more than one digit can stand for a dash/dot/space, the encoding can choose whatever digit they would like.

Decoding a Pollux applies the process in reverse. It starts by mapping the known digits to their corresponding dot/dash/space and looking for complete Morse code characters. A complete Morse code character is one where an uninterrupted series of dots/dashes are delimited by a space. For example: ●●●× at the beginning represents the very familiar letter S (three dots). Finding ×●●× in the middle would represent the letter I (two dots). However, if we had ×● × (with an unmapped digit after the dot), we wouldn't know what the plain text is until we figured out the mapping for the digit.

With that in mind, the strategy for solving a Pollux consists of a set of steps:

1) Build a table of the possibilities for the digits.

0	1	2	3	4	5	6	7	8	9

2) Fill in the table with the known mappings and then just put ●–× for everything else since we don't know what they map to.

3) Underneath the digits of the cipher, fill in the known mappings with the corresponding Morse code character (●, –, ×).

4) Solve. As digits are eliminated, removed them from the possibility table and fill in known mappings under the cipher text. One special case that makes it easier to solve. If you eliminate × as a possibility, leaving ● or –, filling in the corresponding cipher spot with ? makes it easier to find places where a × belongs.

Some good solving rules that help quickly solve a Pollux

1) The first character will never be an ×. If the cipher digit at the start could map to an ×, you can eliminate that choice.

2) There will never be three spaces (×××) in a row. Hence if you find a cipher digit that is tripled, you know that it can't map to a ×.

3) Also looking for three spaces, if you have digits that already map to × and either have a doubled digit next to it which is unknown or ×× next to an unknown, you can eliminate × from that unknown.

4) No Morse letter is more than 4 dots/dashes and all numbers are exactly 5 dots/dashes. If there is a sequence of 6 characters with an unknown and all the remainder are known to be a dot/dash (●–?) then you know that the unknown must be a ×.

5) Not all sequences of 4 dots/dashes are legal Morse characters. (●●—, ●–●–, ––●, and ––––). If you have a pattern that would map to it, you know that you can eliminate it.

15.c. How to solve

Since we are told the mapping of 235689 ciphertext, we can build the following table:

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

Based on that Information we can map the cipher text as:

```
120598110122784733744918059466981433939
3935026296198313
 ●  –××     ●● ×  ●●    × × –× ––××
●●×●×●– ●–●×– ××● ●
   /                    /     E
/
045586671875694659162822303776151766696
3203
  ––×––  × ––× ––× –●×●●● ●  – –  ––– ×–●●
●
```

The first Morse code character can never be an ×,

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

Based on that Information we can map the cipher text as:

```
120598110122784733744918059466981433939
3935026296198313
?● –××?? ?●● ×  ●●   ×?× –× ––××?
●●×●×●– ●–●×–?××●?●
    /                          /
E          /
045586671875694659162822303776151766696
3203
  ––×––  ?× ––× ––×?–●×●●● ● –?–? –––
×–●● ●
```

At this point in time, 4 ciphertext characters still need to be mapped. Looking at the ciphertext, we see the sequence 449 which would result in three ×s in a row if 4 were an ×.

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

Based on that Information we can map the cipher text as:

```
120598110122784733744918059466981433939
3935026296198313
?● –××?? ?●● ×? ●● ??×?× –×?––
××??●●×●×●– ●–●×–?××●?●
    /                          /     E
/
045586671875694659162822303776151766696
3203
 ?––×–– ?× ––×?––×?–●×●●● ●  –?–? –––
×–●● ●
```

At this point in time, 4 ciphertext characters still need to be mapped. Based on the sequence 350262 with 0 possibly being one of ●–×, only × results in a legal Morse code character, so we can mark 0 as being ×.

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

Based on that Information we can map the cipher text as:

```
120598110122784733744918059466981433939
3935026296198313
```

?●×–××??×?●● ×? ●● ??×?××–×?––
××??●●×●×●–×●–●×–?××●?●
T/ / T /
E A R /
045586671875694659162822303776151766696320 3
×?––×–– ?× ––×?––×?–●×●●●×● –?–? ––– ×–●●×●
S
D E

At this point in time, 3 ciphertext characters still need to be mapped. Since 1 can still map to ●– we simply try them and look at the first word or two to see if it makes sense. Trying ● for 1 gives us a chunk: EARN S. Trying – for 1 gives us a chunk: EARM R. Which means we know that 1 must map to ●

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

Based on that Information we can map the cipher text as:

120598110122784733744918059466981433939350 26296198313
●●×–××●●×●●● ×? ●● ??×●××–×?––
××●?●●×●×●–×●–●×–●××●●●
I T/ I E/ T /
E A R N / S
045586671875694659162822303776151766696320 3
×?––×–– ●× ––×?––×●–●×●●●×● –●–● ––– ×–●●×●
R S
D E

At this point in time, 2 ciphertext characters still need to be mapped. Based on the sequence 37761517666 with 7 possibly being one of ●–×, only × results in a legal Morse code character, so we can mark 7 as being ×.

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

Based on that Information we can map the cipher text as:

120598110122784733744918059466981433939350 26296198313

```
●●×–××●●×●●●××?×●●×??×●××–×?––
××●?●●×●×●–×●–●×–●××●●●
I  T/ I  S  /   I     E/ T    /
E A  R   N / S
045586671875694659162822303776151766 6
963203
×?––×––×●××––×?––×●–●×●●●×●××–●–●×–––
×–●●×●
     M  E/ M      R   S   E/ C    O
D   E
```

At this point in time, 1 ciphertext characters still need to be mapped. Since 4 can still map to ●– we simply try them and look at the first word or two to see if it makes sense. Trying ● for 4 gives us a chunk: IT IS EIIE TW HEARN SWME MWRSE COD. Trying – for 4 gives us a chunk: IT IS TIME TO LEARN SOME MORSE CODE. Which means we know that 4 must map to –

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

Based on that Information we can map the cipher text as:

```
120598110122784733744918059466981433 9
393502629619831 3
●●×–××●●×●●●××–×●●×––×●××–×–––××●–
●●×●×●–×●–●×–●××●●●
I  T/ I  S  / T I  M  E/ T O  / L
E A  R   N / S
045586671875694659162822303776151766 6
963203
×–––×––×●××––×–––×●–●×●●●×●××–●–●×–––
×–●●×●
 O   M  E/ M  O   R   S   E/ C    O
D   E
```

Now that we have mapped all the ciphertext characters, the decoded Morse code is the answer:

IT IS TIME TO LEARN SOME MORSE CODE

16. Fractionated Morse Div B Div C

A Fractionated Morse cipher is a combination between a Pollux/Morbit and the K1/K2 alphabet from an Aristocrat. It is important to understand how they are encoded in order to be able to quickly decode them.

The first step is to pick a keyword and construct the alphabet. For example, if the keyword were DULCIMERS, then the alphabet is constructed by removing any duplicate letters in the phrase (of which we have none) and then adding the remainder of the alphabet in order after it. We end up with:

DULCIMERSABFGHJKNOPQTVWXYZ

Placing them into the table to map the morse characters we get:

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

From this we can see that **D** will correspond to ●●● to and **E** will correspond to ●×●. Since the letter **Z** was not used in the keyword, it ends up mapping to ××–. Given this, we can then encode a simple phrase such as CODEBUSTERS by first converting it to Morse code:

C O D E B U S T E R S

–●–●×––×–●●×●×–●●●×●●–×●●●×–×●×●–●×●●●

Next we take the morse code and break it into groups of 3 padding with **×** as necessary, but in this case we got lucky and didn't need any padding. We can then look up the groups of 3 in the table above to generate the cipher text. We already knew that ●●● is **D** to and ●×● is **E** with the others pretty quick to look up.

C O D E B U S T E R S

–●– ●×– ––× –●● ×●× –●● ●×● ●–× ●●● ×–× ●×● –●× ●●●

B R J A T A E M D X E F D

As you should be able to see, the key to solving a Fractionated Morse cipher is to figure out the keyword and recognizing the patterns in the remainder of the alphabet after the keyword. For example if you lean that **N** is **–×–** and **Q** is **×●–** then you immediately know that since there are two slots between them and likewise two letters, you know the mapping of **O** and **P**.

16.a. Solving a Fractionated Morse cipher

Someone has encoded a phrase using the Fractionated Morse cipher and told you that it ends with **EARS**. What does it say?

KMUPKSGHPDWWKDMUVDHVIZSRKPGBILTVORTNL
JMXXEWOMIRDBQIVGCKQQIS

●	●	●	●	●	●	●	●	●	–	–	–	–	–	–	–	–	–	×	×	×	×	×	×	×	×
●	●	●	–	–	–	×	×	×	●	●	●	–	–	–	×	×	×	●	●	●	–	–	–	×	×
●	–	×	●	–	×	●	–	×	●	–	×	●	–	×	●	–	×	●	–	×	●	–	×	●	–

The first step is to covert the **EARS** phrase to morse code and break it into groups of three.

●×● −×● −●× ●●●

Since the cipher text ends in **KQQIS** we immediately see that since all four groups of three are different, there is no way it will map which means that there must be one or two × at the end. Generating the two versions adding the × at the beginning and the end gives us

?×● ×●− ×●− ●×● ●●×

×●× ●−× ●−● ×●● ●××

We can see that the one with a single × at the end has a repeated pattern of ×●− which gives us the mapping:

?×● ×●− ×●− ●×● ●●×

K Q Q I S

allows us to fill in the table:

		S				I												Q						
●	●	●	●	●	●	●	●	●	−	−	−	−	−	−	−	−	×	×	×	×	×	×	×	×
●	●	●	−	−	−	×	×	×	●	●	●	−	−	−	×	×	×	●	●	●	−	−	−	×	×
●	−	×	●	−	×	●	−	×	●	−	×	●	−	×	●	−	×	●	−	×	●	−	×	●	−

K M U P K S G H P D W W

K D M

?×●??????????×●●●×????????????????????

?●??????

U V D H V I Z S R K P G

B I L

????????????????●×●???●●×????×●???????

??●×●???

T V O R T N L J M X X E

W O M

????????????????????????????????????

????????

I R D B Q I V G C K Q Q

I S

●×●?????????×●−●×●?????????×●×●−×●−

●×●●●×

E A R

S

The first thing that we can do is determine where **K** is since we know two of the morse characters. As **?×●** it can be one of **●×●**, **—×●**, or **××●**. However since we already know that I maps to **●×●**, we are left with two choices. Given the position of Q near the end of the list and S already being used, we are left with 8 characters (**RTUVWXYZ**) to take up the 6 slots after it including **××●** which means that where **K** must be **—×●** so we can fill it in and update the cipher:

		S				I								K				Q						
●	●	●	●	●	●	●	●	●	–	–	–	–	–	–	–	–	–	×	×	×	×	×	×	×	×
●	●	●	–	–	–	×	×	×	●	●	●	–	–	–	×	×	×	●	●	●	–	–	–	×	×
●	–	×	●	–	×	●	–	×	●	–	×	●	–	×	●	–	×	●	–	×	●	–	×	●	–

K M U P K S G H P D W W
K D M
—×●?????????—×●●●×?????????????????—
×●??????
T S
U V D H V I Z S R K P G
B I L
????????????????●×●???●●×???—
×●?????????●×●???

T V O R T N L J M X X E
W O M
????????????????????????????????????
????????

I R D B Q I V G C K Q Q
I S
●×●?????????×●—●×●?????????—×●×●—×●—
●×●●●×
R E A R
S

Next we have a couple of paths to take. We could assume that **Z** doesn't appear in the keyword and map it to **××—**. We can also notice that the cipher starts with the letter **T** and the next morse character is a **●** which happens to be the first part of the letter **H** with **THE** being one of the most common words to start a phrase. This gives us

K M U P K S G H P D W W
K D M

−×●●●×●×???−×●●●×????????????????−
×●???●●●
T H E S
U V D H V I Z S R K P G
B I L
×●×??????????????●×●××−●●×???−
×●?????????●×●???
E E/ D
T V O R T N L J M X X E
W O M
??????????????????????●●●??????????
?????●●●

I R D B Q I V G C K Q Q
I S
●×●?????????×●−●×●?????????−×●×●−×●−
●×●●●×
R E A R
S

And we can update the table as:

M		S				I								K				Q	U					
●	●	●	●	●	●	●	●	●	−	−	−	−	−	−	−	−	−	×	×	×	×	×	×	×
●	●	●	−	−	−	×	×	×	●	●	●	−	−	−	×	×	×	●	●	●	−	−	−	×	×
●	−	×	●	−	×	●	−	×	●	−	×	●	−	×	●	−	×	●	−	×	●	−	×	●	−

This turns out to be a really big break since we can see can assume that **QU** is not part of the keyword and the remaining 5 slots correspond to the last 5 letters in the alphabet after **U**. This gives us a table below that fills in a lot of the cipher:

M		S				I								K				Q	U	V	W	X	Y	Z
●	●	●	●	●	●	●	●	●	−	−	−	−	−	−	−	−	−	×	×	×	×	×	×	×	×
●	●	●	−	−	−	×	×	×	●	●	●	−	−	−	×	×	×	●	●	●	−	−	−	×	×
●	−	×	●	−	×	●	−	×	●	−	×	●	−	×	●	−	×	●	−	×	●	−	×	●	−

K M U P K S G H P D W W
K D M
−×●●●×●×???−×●●●×??????????×−−×−−−
×●???●●●
T H E S M O
U V D H V I Z S R K P G
B I L

```
×●××–●??????×–●●×●××–●●×???–
×●??????????●×●???
 E/               E/ D
 T  V  O  R  T  N  L  J  M  X  X  E
W  O  M
???×–●??????????????????●●●×–××–
×???×––???●●●
                                T/ T
 I  R  D  B  Q  I  V  G  C  K  Q  Q
I  S
●×●??????????×●–●×●×–●??????–×●×●–×●–
●×●●●×
            R   E            E A  R
S
```

This also leads to another lucky discovery since we believe that **THE** is the first word, we can guess that **P** must start with an **×**, there is only one slot left and it happens to be right before the letter **Q** which strengthens our guess:

M		S				I								K			P	Q	U	V	W	X	Y	Z
●	●	●	●	●	●	●	●	●	–	–	–	–	–	–	–	–	–	×	×	×	×	×	×	×	×
●	●	●	–	–	–	×	×	×	●	●	●	–	–	–	×	×	×	●	●	●	–	–	–	×	×
●	–	×	●	–	×	●	–	×	●	–	×	●	–	×	●	–	×	●	–	×	●	–	×	●	–

```
 K  M  U  P  K  S  G  H  P  D  W  W
K  D  M
–×●●●×●××●●–×●●●×??????×●●???×––×–––
×●???●●●
T H    E/ U   S                 M  O
 U  V  D  H  V  I  Z  S  R  K  P  G
B  I  L
×●××–●??????×–●●×●××–●●×???–
×●×●●??????●×●???
 E/           D   E/ D        E
 T  V  O  R  T  N  L  J  M  X  X  E
W  O  M
???×–●??????????????????●●●×–××–
×???×––???●●●
                                T/ T
 I  R  D  B  Q  I  V  G  C  K  Q  Q
I  S
```

●×●??????????×●−●×●×−●??????−×●×●−×●−
●×●●●×
R E E A R
S

Seeing the start of the phrase as **THE US?** certainly sounds like it starts out **THE USE**, so we can assume that **G** maps to **●××**. Filling that in gives us:

M		S				I		G						K			P	Q	U	V	W	X	Y	Z
●	●	●	●	●	●	●	●	●	−	−	−	−	−	−	−	−	−	×	×	×	×	×	×	×	×
●	●	●	−	−	−	×	×	×	●	●	●	−	−	−	×	×	×	●	●	●	−	−	−	×	×
●	−	×	●	−	×	●	−	×	●	−	×	●	−	×	●	−	×	●	−	×	●	−	×	●	−

K M U P K S G H P D W W
K D M
−×●●●×●××●●−×●●●×●××???×●●???×−−×−−−
×●???●●●
T H E/ U S E/ M O
U V D H V I Z S R K P G
B I L
×●××−●??????×−●●×●××−●●×???−
×●×●●●××???●×●???
E/ D E/ D E S /
T V O R T N L J M X X E
W O M
???×−●??????????????????●●●×−××−
×???×−−???●●●
T/ T
H
I R D B Q I V G C K Q Q
I S
●×●??????????×●−●×●×−●●××???−×●×●−×●−
●×●●●×
R E D / E A R
S

Looking at the end, we have a word that ends in **EARS** and has either four morse symbols ending in **−** or is two letters. A quick look at the four symbol morse characters ending with **−** gives us either **V J** or **Y** with **YEARS** being a very good choice. Filling the mapping for **C** gives us:

M		S				I		G		C				K			P	Q	U	V	W	X	Y	Z
●	●	●	●	●	●	●	●	●	−	−	−	−	−	−	−	−	−	×	×	×	×	×	×	×	×
●	●	●	−	−	−	×	×	×	●	●	●	−	−	−	×	×	×	●	●	●	−	−	−	×	×

●	–	×	●	–	×	●	–	×	●	–	×	●	–	×	●	–	×	●	–	×	●	–	×	●	–

K M U P K S G H P D W W
K D M
–×●●●×●××●●–×●●●×●××???×●●???×––×–––
×●???●●●
T H E/ U S E/ M O
U V D H V I Z S R K P G
B I L
×●××–●??????×–●●×●××–●●×???–
×●×●●●××???●×●???
E/ D E/ D
T V O R T N L J M X X E
W O M
???×–●??????????????????●●●×–××–
×???×––???●●●
T/ T
H
I R D B Q I V G C K Q Q
I S
●×●??????????×●–●×●×–●●××–●––×●×●–×●–
●×●●●×
R E D / Y E A R
S

Also seeing the **H???RED YEARS** only leaves us with one word that fits there – **HUNDRED YEARS** – so we get the mapping of a few more letters:

M		S			R	I		G	B	C	D				K			P	Q	U	V	W	X	Y	Z
●	●	●	●	●	●	●	●	●	–	–	–	–	–	–	–	–	–	×	×	×	×	×	×	×	×
●	●	●	–	–	–	×	×	×	●	●	●	–	–	–	×	×	×	●	●	●	–	–	–	×	×
●	–	×	●	–	×	●	–	×	●	–	×	●	–	×	●	–	×	●	–	×	●	–	×	●	–

K M U P K S G H P D W W
K D M
–×●●●×●××●●–×●●●×●××???×●●???×––×–––
×●–●×●●●
T H E/ U S E/ M O
R S
U V D H V I Z S R K P G
B I L
×●××–●–●×???×–●●×●××–●●×●–×–×●×●●●××–
●●●×●???

```
 E/ C        D   E/ D   A  T E S  / B
 T  V  O  R  T  N  L  J  M  X  X  E
W  O  M
???×–●?××●–×???????????●●●×–××–
×???×––?××●●●
                                T/ T
/ H
 I  R  D  B  Q  I  V  G  C  K  Q  Q
I  S
●×●●–×–●×–●●×●–●×●×–●●××–●––×●×●–×●–
●×●●●×
  U   N  D   R   E D  / Y    E A  R
S
```

This tells us that **O** must map to **?××** and since **G** already maps to **●××** it only leaves **–××** for **O** which is conveniently right next to **P**. (Remember that **×××** isn't mapped to anything). As we fill that in, we see **T?O HUNDRED YEARS** at the end which could only be **TWO HUNDRED YEARS** giving us the mapping for **E**. Likewise **MORSE C?DE** must be **MORSE CODE**:

M		S		E	R	I		G	B	C	D		H		K		O	P	Q	U	V	W	X	Y	Z
●	●	●	●	●	●	●	●	●	–	–	–	–	–	–	–	–	–	×	×	×	×	×	×	×	×
●	●	●	–	–	–	×	×	×	●	●	●	–	–	–	×	×	×	●	●	●	–	–	–	×	×
●	–	×	●	–	×	●	–	×	●	–	×	●	–	×	●	–	×	●	–	×	●	–	×	●	–

```
 K  M  U  P  K  S  G  H  P  D  W  W
K  D  M
–×●●●●×●××●●–×●●●×●××–––×●●–●××––×–––
×●–●×●●●
T H    E/ U   S   E/ O   F   / M  O
R   S
 U  V  D  H  V  I  Z  S  R  K  P  G
B  I  L
×●××–●–●×–––×–●●×●××–●●×●–×–×●×●●●××–
●●●×●???
 E/ C    O   D   E/ D   A  T E S  / B
 T  V  O  R  T  N  L  J  M  X  X  E
W  O  M
???×–●–××●–×???????????●●●×–××–×●––
×–––××●●●
```

K / A T/ T W
O / H
I R D B Q I V G C K Q Q
I S
●×●●–×–●×–●●×●–●×●×–●●××–●––×●×●–×●–
●×●●●×
U N D R E D / Y E A R
S

We can pretty much sight read the rest of the cipher and fill in the remaining letters:

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

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

This gives us the mapping of every letter except A and F and we can see that the keyword would have to be **MASTERING**.

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

17. Cryptarithm Div B Div C

17.a. General Solving Rules

In general, the strategy for an Aristocrat is:
Fill in letters from any clues you are given
Look for single letter words which will generally be **A** or **I**
Check the frequency. The most common letters in English are **ETAOIN**.
Look for contractions (**DON'T**, **DOESN'T**)
Look for two and three letter words
Look for patterns "**IT IS**" and "**THAT**" are good ones
Look for double letters
A much more detailed guide can be found on Puzzle Baron's Cryptograms site at https://cryptograms.puzzlebaron.com/tutorial.php

17.b. Solving a Cryptarithm

```
 SOCIAL     social
+ SOLAR     solar   24687
-------
 95310
VEHICLE    vehicle
```

	0	1	2	3	4	5	6	7	8	9
A										
C										
E										
H										
I										
L										
O										
R										
S										
V										

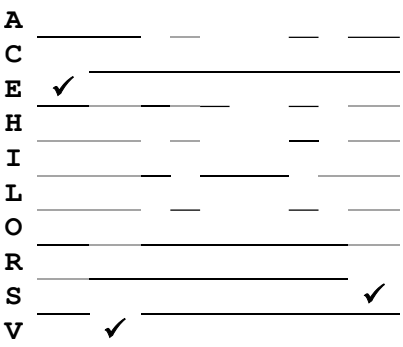
Immediately we know that **V** must be 1 because you can only carry a single digit from the previous column addition. Furthermore, since there is only one digit in the previous column, it must be a 9 in order to carry from the column before that which means that the first two digits of the final result must be 10 telling us the mappings of **V** and **E**. We can mark that in the table.

	0	1	2	3	4	5	6	7	8	9
A										
C										
E		✓								
H										
I										
L										
O										
R										
S										
V		✓								

```
 SOCIAL     social
S  V
+ SOLAR     solar   24687
-------
 95310
VEHICLE    vehicle
```

Some quick observations we can learn from what we have filled in so far:

In the first column we have: **L+R=10** which because of the numbers already mapped can only be 2+8, 3+7 or 4+6 in either order.
In the second column we add the carry from the first column to **A+A** giving us L which must be odd. Based on what we learned in the first column, we know that **L** must be either 3 or 7 which means **A** must be one of 1, 3, 6 or 8. We can quickly try all 4 options
A=1 won't work since **V=1** already
For **A=3** we end up with **L=7**, but **L+R=10** means that **R** would also be 3 so we can't use that.
For **A=6** we have **L=3** which forces **R=7** which means it is a possibility.
For **A=8** we get **L=7** which forces **R=3** leaving it as a possibility.
Either way we know that either **L** or **R** is 3 and the other is 7 and that **A** must be either 6 or 8, so we mark it in the table. We also know that since **A > 5** there is a carry into the next column



	0	1	2	3	4	5	6	7	8	9

SOCIAL 9ocial
S V

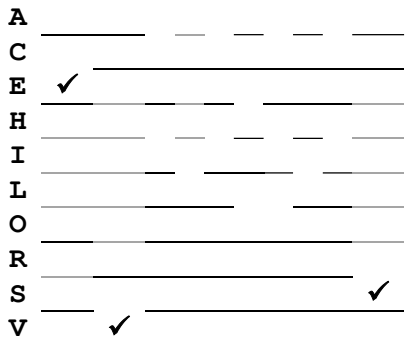
+

SOLAR + 9olar 24687
95310
VEHICLE 10hicl0

With the next column, we know that (carry from previous column) **1+I+L=C**. Since **L** must be either 3 or 7 and **I** and **C** are both limited to only five possible values, we look at the ten possible combinations to see which work.

L	I	1+I+L=C	Notes
3	2	6	
3	4	8	
~~3~~	~~5~~	~~9~~	**S=9**
~~3~~	~~6~~	**~~(carry)~~**~~0~~	**E=0**
3	8	**(carry)**2	
~~7~~	~~2~~	**~~(carry)~~**~~0~~	**E=0**
7	4	**(carry)**2	
~~7~~	~~5~~	**~~(carry)~~**~~3~~	**C≠3**
7	6	**(carry)**4	
7	8	**(carry)**6	

Immediately this eliminates **C=5** and **I=5** leaving only **H** or **O** to be 5.
With H and O in mind, we notice that (possible carry)**+O+9=H** (with a carry). This tells us that **O>H** and that either **O-1=H** or **O-2=H** depending on the carry from the previous column. Since one of them must be 5 we either have **O=5** and **H=4** or **H=5** and **O=6**. This means that there can not be a carry from **C+O** and **C+O<9**.



With this information in hand, we fill in our table and eliminate quite a few options:

SOCIAL 9ocial
S V

	0	1	2	3	4	5	6	7	8	9

```
 + SOLAR    +   9olar   24687 95310
VEHICLE      10hicl0
```

The only column we haven't looked at is the (possible carry from previous column+)C+O=I. Taking into account what we learned with the I+L column and knowing that there are only two possible values for I and 4 possible values for C or I we can test them out quickly in a table.

C	O	Carry+C+O=I	Notes
2	5	8	
2	6	9	S=9
4	5	(carry)0	E=0
4	6	(carry)1	V=1
6	5	(carry)2	
6	5	(carry)3	I≠3
8	5	(carry)3	I≠3
8	6	(carry)4	

Since we previously determined that C+O<9 this tells us that the only possible answer is that C=2, O=5 and I=8. Since we know what when O=5, H=4 we can fill that in too.

This leaves A=6 as the only option. Previously we also determined that for A=6, L=3 and R=7 which gives us the final table and we can fill in the letters for the answer.

	0	1	2	3	4	5	6	7	8	9
A							✓			
C			✓							
E	✓									
H					✓					
I										✓
L				✓						
O						✓				
R								✓		
S										✓
V		✓								

```
SOCIAL
952863
```

```
CHAIR  SOLVE
 + SOLAR    +   95367
24687 95310
VEHICLE      1048230
```

18. Tap Code Cipher Div A

The Tap Code cipher is an easy cipher to remember and can be solved in two ways. One way is to write down the letters in a table and then use the sets of taps to look up the entry in the table. The other way is to remember five letters and solve it on the fly.

18.a. A Tap Code Cipher to decode

Your friend just gave you this message written in a Tap Code Cipher. What does it say?

●●● ● ● ●●●●● ●●●● ●●●● ●●●● ●●● ●● ●●● ● ● ●●●●● ● ● ●●●●●

●●●● ●●● ●●● ●●●● ●●● ●● ● ●●●●● ●● ● ●●●● ●●●●● ●●● ●●●

18.b. Solving a Tap Code Cipher it with a table

The first thing to do is create a table to map the letters. Just draw a grid of 5x5 boxes:

Then fill in the table with the letters A-Z remembering that C and K go into the same spot. You can also put numbers across the rows and columns to aid in decoding.

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

With the table in hand, the next step is to count the number of taps and group them in sets of 2

●●● ● ● ●●●●● ●●●● ●●●● ●●●● ●●● ●● ●●● ● ● ●●●●● ● ● ●●●●●

3 1/1 5 /4 4 /4 3 /2 3 /1 1/5 1/1 5

●●●● ●●● ●●● ●●●● ●●● ●● ● ●●●●● ●● ● ●●●● ●●●●● ●●● ●●●

4 3 /3 4 /3 2 /1 5 /2 1/4 5 /3 3

It is important that the count ends with a pair of two numbers. If there is only one, then carefully go back and find where a set got skipped.

With the numbers in hand, it is a matter of using the first in the pair to look up the row and the second to pick the column and then put the letter in place:

●●● ● ● ●●●●● ●●●● ●●●● ●●●● ●●● ●● ●●● ● ● ●●●●● ● ● ●●●●●

3 1/1 5 /4 4 /4 3 /2 3 /1 1/5 1/1 5

L E T S H A V E

●●●● ●●● ●●● ●●●● ●●● ●● ● ●●●●● ●● ● ●●●● ●●●●● ●●● ●●●

4 3 /3 4 /3 2 /1 5 /2 1/4 5 /3 3

S O M E F U N

This gives us the answer, The only thing that you may have to do is choose whether something was a **C** or a **K** based on the word.

18.c. Solving a Tap Code Cipher on the fly by remembering 5 letters

Another way to solve pretty quickly without the table is to remember the five letters in the first column: **AFLQV** Just start with the first set and put the letters under each tap until you get the end. Then for the next set, you start with the letter you ended up with and advance it for each one.

●●● ● ● ●●●●● ●●●● ●●●● ●●●● ●●● ●● ●●● ● ● ●●●●● ● ● ●●●●●

AFL L A ABCDE AFLQ QRST AFLQ QRS AF FGH A A AFLQV V A ABCDE

L E T S H A V E

●●●● ●●● ●●● ●●●● ●●● ●● ● ●●●●● ●● ● ●●●● ●●●●● ●●● ●●●

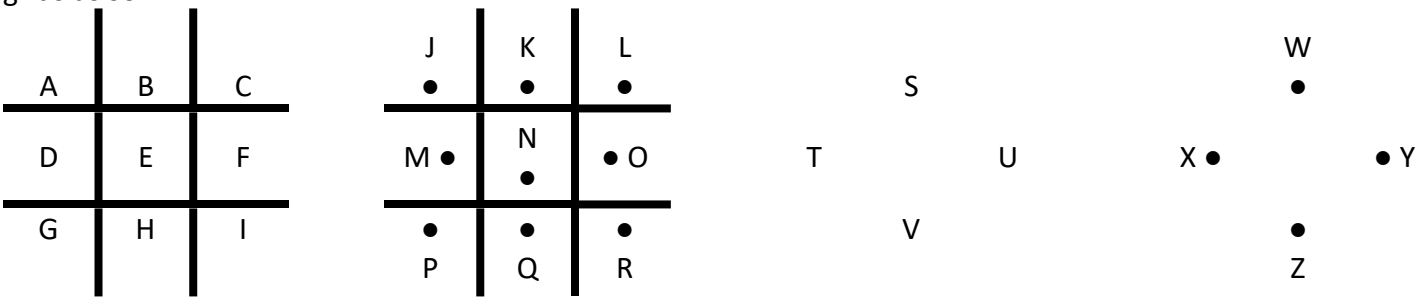
AFLQ QRS AFL LMNO AFL LM A ABCDE AF F AFLQ QRSTU AFL LMN

S O M E F U N

The last letter in each set is the one to use. Once again, you may have to change a **C** to be a **K** based on the word.

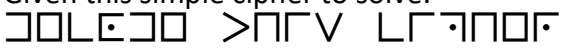
19. PigPen/Masonic Cipher Div A

The PigPen cipher is an easy cipher requires remembering a simple setup in order to create the key. With that key, decoding is just looking up the symbols in the key. All the students need to do is create two tic-tac-toe grids and two X grids and then fill them in with the alphabet putting dots on the second of the grids as so:



19.a. Solving A PigPen Cipher

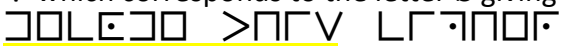
Given this simple cipher to solve:



The symbols can be decoded by looking at the letters in the corresponding spot in the grids. The first symbol ⊐ corresponds to the left center of the first grid, hence the letter **D**. The next symbol □ Corresponds to the center of the first grid giving us the letter **E**. The next ∟ is the upper right for the letter **C**. With the fourth letter ⊡ we have a dot in it, so the letter comes from the second grid in the right middle for the letter **O**. The next two are repeats of the first to leaving us with **DECODE** so far.

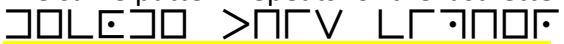
DECODE

The second word starts with ⋗ which corresponds to the left half of the cross for the letter **T**. This is followed by ⊓⌜ which is **HI**. Lastly we have ⋁ which corresponds to the letter **S** giving us **THIS** for the second word.



DECODE THIS

The same pattern repeats for the last letters resulting in



DECODE THIS CIPHER

20. Nihilist Cipher Div B Div C

The Nihilist cipher uses two keywords to encode the plaintext. The first is used to construction a Polybius Square which is used to map all of the letters to numbers. The second keyword is used to encode the plaintext, applying each letter in the keyword in sequence in just the same way that the Vigenère cipher works.

Constructing the Polybius Square works in a manner like a K1/K2 alphabet with the exception that the letter **J** is not used. In general, if you had a keyword with the letter **J**, you would substitute the letter **I**. Once you have the Polybius keyword, you then fill out the remainder of the alphabet skipping any letters in the keyword. For example, if we take the keyword **FASHIONED** we can start the Polybius square as:

	1	2	3	4	5
1	F	A	S	H	I
2	O	N	E	D	
3					
4					
5					

We then fill the remaining squares row by row with the unused letters of the alphabet (skipping **J** of course): **BCGKLMPQRTUVWXYZ** giving us:

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

From this Polybius Square we now have the mappings for all the letters we would use in the cipher. **F** being in the first row of the first column maps to **11** while **E** in the third column of the second row maps to **23** and **Z** all at the end maps to **55**.

Now that we have the mapping, we need to pick an encryption keyword. This needs to be a different keyword from the Polybius keyword but is often related. For this example, we will pick **SENSE**. For convenience we can go ahead and map it to the values as **13 23 22 13 23**.

With our Square and encryption keyword in hand we can take on the task of encrypting the plaintext. We will demonstrate it with the plaintext of **EASY CIPHER EXAMPLE**. The Keyword is repeated for each letter in the plaintext starting over when all the letters in the keyword are used up. The Polybius Values are determined for each letter and the final ciphertext is simply the sum of the two numbers.

Plaintext	E	A	S	Y		C	I	P	H	E	R		E	X	A	M	P	L	E
Polybius Value	23	12	13	54		31	15	41	14	23	43		23	53	12	35	41	34	23
Keyword	S	E	N	S		E	S	E	N	S	E		S	E	N	S	E	S	E
Keyword Value	13	23	22	13		23	13	23	22	13	23		13	23	22	13	23	13	23
Ciphertext	36	35	35	67		54	28	64	36	36	66		36	76	34	48	64	47	46

The encrypted ciphertext is **36 35 35 67 54 28 64 36 36 66 36 76 34 48 64 47 46**. It is worth noting that both the **E/S** combinations and **H/N** combinations both encode to the same value **36**, much as you see with the Vigenère cipher.

20.a. Solving a Nihilist Cipher given the keys

Problem to solve:

Given a Polybius key of **SCIENCE OLYMPIAD** and an encoding key of **FUN** decode the following quote by Criss Jami that has been encoded using the Nihilist Cipher.

79 92 29 67 64 50 69 65 26 79 63 56 65 73 37 48 66 50

48 82 49 79 65 59 45 102 27 46 65 26 45 64 26 45 92 66

79 96 28 49 86 66 59 82 48 55 102 60 47 96

How to solve it:

The first step is to use the key to construct the Polybius square. We do this by eliminating all the duplicate letters and then adding all the remaining letters of the alphabet (remembering that I and J count as the same letter) in the same way that we would construct a K1/K2 alphabet. This gives us:

SCIENOLYMPADBFGHKQRTUVWXZ

We can use this to fill in the Polybius square row by row giving us:

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

This tells us the mapping values for all of the letters. For example, in row 3, column 4 we have the first letter of our encoding key **F** which gives us the value **34**. The second letter **U** is in Row 5, column 1 mapping to **51** and **N** is in Row 1 column 5 mapping to **15**. Putting them all together gives us an encoding key of **34 51 15**.

The next step is to write them under each of the cipher text values in the problem repeating when we hit the end of the key as you can see with the *italic* values below:

79 92 29 67 64 50 69 65 26 79 63
56 65 73 37 48 66 50
34 51 15 34 51 15 34 51 15 34 51
15 34 51 15 34 51 15

48 82 49 79 65 59 45 102 27 46 65
26 45 64 26 45 92 66
34 51 15 34 51 15 34 51 15 34 51
15 34 51 15 34 51 15

79 96 28 49 86 66 59 82 48 55 102
60 47 96
34 51 15 34 51 15 34 51 15 34 51
15 34 51

Once we have the values in place we do a simple subtraction from the encoded value: For example the first one 79-34 = 45. All the values are highlighted yellow below:

79 92 29 67 64 50 69 65 26 79 63
56 65 73 37 48 66 50
34 51 15 34 51 15 34 51 15 34 51
15 34 51 15 34 51 15
45 41 14 33 13 35 35 14 11 45 12
41 31 22 22 14 15 35

48 82 49 79 65 59 45 102 27 46 65
26 45 64 26 45 92 66
34 51 15 34 51 15 34 51 15 34 51
15 34 51 15 34 51 15
14 31 34 45 14 44 11 51 12 12 14
11 11 13 11 11 41 51

79 96 28 49 86 66 59 82 48 55 102 60 47 96

34 51 15 34 51 15 34 51 15 34 51 15 34 51

45 45 13 15 35 51 25 31 33 21 51 45 13 45

From this point it is just a matter of using the numbers in the Polybius square to select the row/column and get the letter. The first value **45** is Row 4, Column 5 which has the letter **T**. The next value **41** is Row 4, Column 1 which is the letter **H**. Repeat the process for all the remaining values to get:

79 92 29 67 64 50 69 65 26 79 63 56 65 73 37 48 66 50

34 51 15 34 51 15 34 51 15 34 51 15 34 51 15 34 51

45 41 14 33 13 35 35 14 11 45 12 41 31 22 22 14 15 35

T H E B I G G E S T C H A L L E N G

48 82 49 79 65 59 45 102 27 46 65 26 45 64 26 45 92 66

34 51 15 34 51 15 34 51 15 34 51 15 34 51 15 34 51

14 31 34 45 14 44 11 51 12 12 14 11 11 13 11 11 41 51

E A F T E R S U C C E S S I S S H U

79 96 28 49 86 66 59 82 48 55 102 60 47 96

34 51 15 34 51 15 34 51 15 34 51 15 34 51

45 45 13 15 35 51 25 31 33 21 51 45 13 45

T T I N G U P A F T E R I T

Reading the letters off and adding in spaces gives us the plain text: **The biggest challenge after success is shutting up about it**.

20.b. Solving a Nihilist Cipher via cryptanalysis

Problem to solve:

The following quote by Abhijit Naskar has been encoded using the Nihilist Substitution cipher. You have been told that the decoded text starts with **SOMETIMES**. What does it decrypt to?

97 82 57 45 98 74 57 45 97 86 84 78 64 52 88 66 64 86

86 85 98 73 97 75 104 55 94 78 98 86 94 77 88 63 64 67

88 65 88 75 98 73 54 75 75 93 76 75 104 85

Steps to solution

The process of cryptanalysis is straightforward with the information given.

1. Determine the keyword length.
2. Map the keyword values to determine possible positions in the Polybius square.
3. Subtract the known keyword values to determine the plaintext square positions.
4. Fill in the Polybius square with known information.
5. Iterate over the cipher and Polybius square filling in information until complete.

Determining the Keyword Length

Fortunately for the Nihilist, you are guaranteed that for each mapping letter, there can only be 5 unique values for the last digit, so we can do a count of the number of times that the last digit occurs. Here's a simple way to think about it. Since the last digit for the plaintext mapping comes from the column and there are only 5 columns, adding 5 unique digits to whatever digit is for the keyword at that position can only produce 5 different values. If we had a 3-letter keyword, the mapping looks like this:

K1 K2 K3 **K1** K2 K3 **K1** K2 K3 **K1** K2 K3 **K1** K2 K3 **K1** K2 K3

97 82 57 45 98 74 57 45 97 86 84 78 64 52 88 66 64 86

K1 K2 K3 **K1** K2 K3 **K1** K2 K3 **K1** K2 K3 **K1** K2 K3 **K1** K2 K3

86 85 98 73 97 75 104 55 94 78 98
86 94 77 88 63 64 67

K1 K2 K3 **K1** K2 K3 **K1** K2 K3 **K1** K2
K3 **K1** K2
88 65 88 75 98 73 54 75 75 93 76
75 104 85

We can build a little table to track the digits for the 3-letter keyword and just make a mark if we find the last digit in that position. It is worth observing that there is no possibility that the last digit will be a 1 since the smallest column number in the Polybius square is 1 and we all know that 1+1 = 2.

9**7** 82 57 4**5** 98 74 5**7** 45 97 8**6** 84
78 6**4** 52 88 6**6** 64 86

8**6** 85 98 7**3** 97 75 10**4** 55 94 7**8** 98
86 94 77 88 63 64 67

88 65 88 75 98 73 54 75 75 93 76
75 104 85

	2	3	4	5	6	7	8	9	0
K1		X	X	X	X	X	X		
K2									
K3									

As you can see, once we get to the 78 on in the middle of the second line, we have already found 6 different values which tells us the keyword can't be 3 letters long. So, let's try the same table with every 4th position to see if the keyword is 4 letters long.

9**7** 8**2** 5**7** 4**5** 9**8** 7**4** 5**7** 4**5** 9**7** 8**6** 8**4**
7**8** 6**4** 5**2** 8**8** 6**6** 6**4** 8**6**

8**6** 8**5** 9**8** 7**3** 9**7** 7**5** 10**4** 5**5** 9**4** 7**8** 9**8**
8**6** 9**4** 7**7** 8**8** 6**3** 6**4** 6**7**

8**8** 6**5** 8**8** 7**5** 9**8** 7**3** 5**4** 7**5** 7**5** 9**3** 7**6**
7**5** 10**4** 8**5**

	2	3	4	5	6	7	8	9	0
K1			X	X		X	X		
K2	X	X	X	X	X				
K3			X		X	X	X		
K4				X	X	X	X		

This looks really promising as we get all the way through all the letters without having more than 5 results. We could assume that the keyword is 4 letters long and go on to the next step, but it is worth doing a quick sanity check for 5 letters:

9**7** 82 57 45 98 7**4** 57 45 97 86 8**4**
78 64 52 88 6**6** 64 86

86 85 9**8** 73 97 75 104 5**5** 94 78 98
86 9**4** 77 88 63 64 6**7**

88 65 88 75 9**8** 73 54 75 75 9**3** 76
75 104 85

	2	3	4	5	6	7	8	9	0
K1		X	X	X	X	X	X		
K2									
K3									
K4									
K5									

As we can see, when we get to the **93** we have 6 different values for the last digit so we know that the keyword can't be 5 letters long. We can also do the same thing to test for a 6-letter keyword and discover that for the last position there are 6 different values:

	2	3	4	5	6	7	8	9	0
K1			X		X	X	X		
K2	X			X		X			
K3			X	X		X	X		
K4		X		X	X		X		
K5			X		X	X	X		
K6		X	X	X	X	X	X		

This gives us a high confidence that the keyword is 4 letters long and we can proceed to the next step with that assumption.

Mapping the Keyword Values

With our table we created when checking the possibilities for a 4-letter keyword, we also learned a couple of things about what column the keyword must be in by looking at the spread of the digits we found.