Cryptography: Vigenère and Kasiski

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- The Vigenère cipher was developed and was thought to tackle these problems.

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- The use of polyalphabetic ciphers is thought to have originated with Leon Battista Alberti in 1467.

Vigenère Cipher

- Attributed to Blaise de Vigenère, it was known as 'le chiffre indéchiffrable': the unbreakable cipher. As it turns out, de Vigenère's original cipher was actually more secure than that which came to bear his name.
- Used for many centuries, this was the state of the art, and truly thought to be unbreakable.

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- The alphabets form a square: the Vigenère square, or *tabula recta*.

	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

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plain	i	n	v	a	d	e	a	t	d	a	w	n	o	n	f	r	i	d	a	y
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- Can also be thought of in terms of modular arithmetic:

keyword	2	14	3	4	18	2	14	3	4	18	2	14	3
plaintext	8	13	21	0	3	4	0	19	3	0	22	13	14
ciphertext	10	1	24	4	21	6	14	22	7	18	24	1	17

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- Encryption is achieved by performing the addition

$$c_i = m_i + k_i \mod 26,$$

where m_i is the ith letter of the message and k_i is the ith letter of the keyword repeated over and over again.

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- A few people were involved in the cracking of this cipher, including quite a famous name in computing history.

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  - These letters must have used the same row of the Vigenère square.

Breaking Vigenère

ZSHRSNAYEHVRHIUIZZQZXHWEFLXPOJFCXEFJAJMLSEURXXSVZXAGSEFYKCHYMXMLWJISKPRN
MWUIWESATXQYQHDISEXCTRRTXSLIZPNCBRHVXPBKSEOILKFVMXXVHYMRFEBJMRWCSKMWFSFK
MPTWVZESPRHYMXTWAVZFNWWVPXAIAJQPOIGRNSNXHYQMKZOIUSNWQFZGXVBJFLXCKVDILGFL
FMGMGVPEGHGKGHBIRGQVAEDJMPFSGKMWGEFIAAECOJMQTRKZFLTQWTDSLGCGQQBKVKEGKYHZ
ZMLIHYQXKEBJUIGXQIQEMYFVEXAEHJIEKQOEPQNPHZBPRMBRPVHTCWIEMIFNUXAMBWURBXST
AQIPOTQRVCAVZAXRHKAEGHTIASOIFKTMLKZFNITFCLFXAIWIXMMXZVMJYEWIEWXVSEQMGXVV
UVTWGLDEGGSFRXAIWIQQIMFVAZXVARFXXVWKUWISGJUFEIHYMXMLSZZJNWCIUENRRVDXAIAZ
OVHWQFBIWSHYQWTQSEASGIURHITXVFGKAXHFFLXSZUQVPSFCPWHJGGMGXEGJAYKGSJAJAYAR
ZHTRUVDSKXVFGKAXCWFLXQCEXCMSRZEQBWGKTIBHSRAJEMTVGTHRHYQQTWWDBSLWWSXIHVWD
BVHFOSXIBXWJOYKMCLEXHVSTMPEWCDQSYXVVYIGXOCTEUMHJAJMLCJQHXTOIFIWHOPEEMQCJ
FXXVFVEXKMOCYIGJOEOMXHHYQVXQWXTXUICKTIKQSEGTHRARDWIIFYMTLMBWQVBSFKAXAIAJ
QPOIGRZHKIOUKXHASCOSFIODUWLMCEMVRIBKQVIVWJQCXXOTDSLWHYQKNPTFRWIEQVYMGHGK
TEMEFVFSHYFDURWWOJAYKWOIQXHXVFEIHJHYQFXEGKEXAEHGQVBWVZZXXPZVOXLZOJFEGHQF
APTRRLZWRQDRFLXXWTDIZEFUQHMLWJQEKXVNUXAIBMUSNWSPQWTRRJXSPPMRZHLYFVXCWVSN
FLXMFGXEGWOXMMGWHLE

- Assume we know the key length: $k = 6$. We'll look into how to figure this out later.

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ZSHRSNAYEHVRHIUIZZQZXHWEFLXPOJFCXEFJAJMLSEURXXSVZXAGSEFYKCHYMXMLWJISKPRN
MWUIWESATXQYQHDISEXCTRRTXSLIZPNCBRHVXPBKSEOILKFVMXXVHYMRFEBJMRWCSKMWFSFK
MPTWVZESPRHYMXTWAVZFNWWVPXAIAJQPOIGRNSNXHYQMKZOIUSNWQFZGXVBJFLXCKVDILGFL
FMGMGVPEGHGKGHBIRGQVAEDJMPFSGKMWGEFIAAECOJMQTRKZFLTQWTDSLGCGQQBKVKEGKYHZ
ZMLIHYQXKEBJUIGXQIQEMYFVEXAEHJIEKQOEPQNPHZBPRMBRPVHTCWIEMIFNUXAMBWURBXST
AQIPOTQRVCAVZAXRHKAEGHTIASOIFKTMLKZFNITFCLFXAIWIXMMXZVMJYEWIEWXVSEQMGXVV
UVTWGLDEGGSFRXAIWIQQIMFVAZXVARFXXVWKUWISGJUFEIHYMXMLSZZJNWCIUENRRVDXAIAZ
OVHWQFBIWSHYQWTQSEASGIURHITXVFGKAXHFFLXSZUQVPSFCPWHJGGMGXEGJAYKGSJAJAYAR
ZHTRUVDSKXVFGKAXCWFLXQCEXCMSRZEQBWGKTIBHSRAJEMTVGTHRHYQQTWWDBSLWWSXIHVWD
BVHFOSXIBXWJOYKMCLEXHVSTMPEWCDQSYXVVYIGXOCTEUMHJAJMLCJQHXTOIFIWHOPEEMQCJ
FXXVFVEXKMOCYIGJOEOMXHHYQVXQWXTXUICKTIKQSEGTHRARDWIIFYMTLMBWQVBSFKAXAIAJ
QPOIGRZHKIOUKXHASCOSFIODUWLMCEMVRIBKQVIVWJQCXXOTDSLWHYQKNPTFRWIEQVYMGHGK
TEMEFVFSHYFDURWWOJAYKWOIQXHXVFEIHJHYQFXEGKEXAEHGQVBWVZZXXPZVOXLZOJFEGHQF
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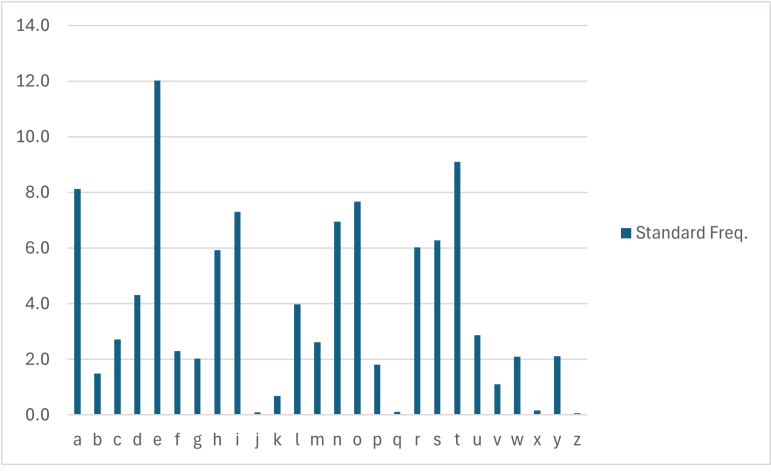
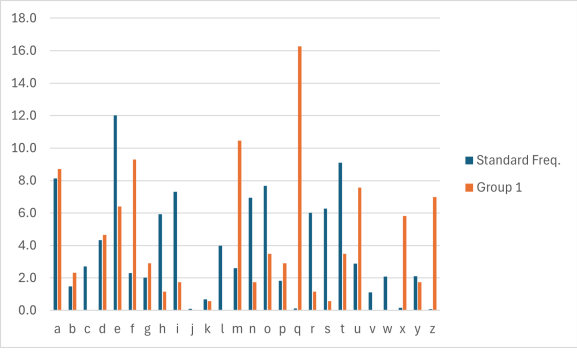
MWUIWESATXQYQHDISEXCTRRTXSLIZPNCBRHVXPBKSEOILKFVMXXVHYMRFEBJMRWCSKMWFSFK
MPTWVZESPRHYMXTWAVZFNWWVPXAIAJQPOIGRNSNXHYQMKZOIUSNWQFZGXVBJFLXCKVDILGFL
FMGMGVPEGHGKGHBIRGQVAEDJMPFSGKMWGEFIAAECOJMQTRKZFLTQWTDSLGCGQQBKVKEGKYHZ
ZMLIHYQXKEBJUIGXQIQEMYFVEXAEHJIEKQOEPQNPHZBPRMBRPVHTCWIEMIFNUXAMBWURBXST
AQIPOTQRVCAVZAXRHKAEGHTIASOIFKTMLKZFNITFCLFXAIWIXMMXZVMJYEWIEWXVSEQMGXVV
UVTWGLDEGGSFRXAIWIQQIMFVAZXVARFXXVWKUWISGJUFEIHYMXMLSZZJNWCIUENRRVDXAIAZ
OVHWQFBIWSHYQWTQSEASGIURHITXVFGKAXHFFLXSZUQVPSFCPWHJGGMGXEGJAYKGSJAJAYAR
ZHTRUVDSKXVFGKAXCWFLXQCEXCMSRZEQBWGKTIBHSRAJEMTVGTHRHYQQTWWDBSLWWSXIHVWD
BVHFOSXIBXWJOYKMCLEXHVSTMPEWCDQSYXVVYIGXOCTEUMHJAJMLCJQHXTOIFIWHOPEEMQCJ
FXXVFVEXKMOCYIGJOEOMXHHYQVXQWXTXUICKTIKQSEGTHRARDWIIFYMTLMBWQVBSFKAXAIAJ
QPOIGRZHKIOUKXHASCOSFIODUWLMCEMVRIBKQVIVWJQCXXOTDSLWHYQKNPTFRWIEQVYMGHGK
TEMEFVFSHYFDURWWOJAYKWOIQXHXVFEIHJHYQFXEGKEXAEHGQVBWVZZXXPZVOXLZOJFEGHQF
APTRRLZWRQDRFLXXWTDIZEFUQHMLWJQEKXVNUXAIBMUSNWSPQWTRRJXSPPMRZHLYFVXCWVSN
FLXMFGXEGWOXMMGWHLE

Patterns in the Standard Frequencies



Letter Group 1



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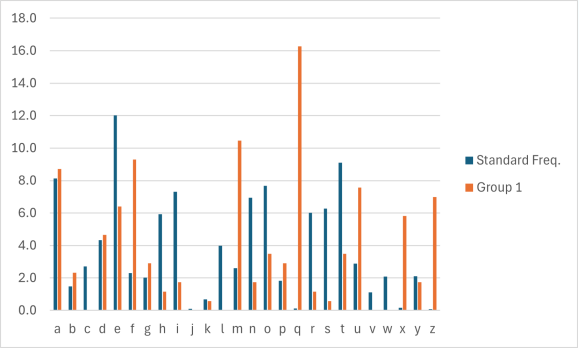

- Each group has been shifted by the same value: a Caesar cipher.

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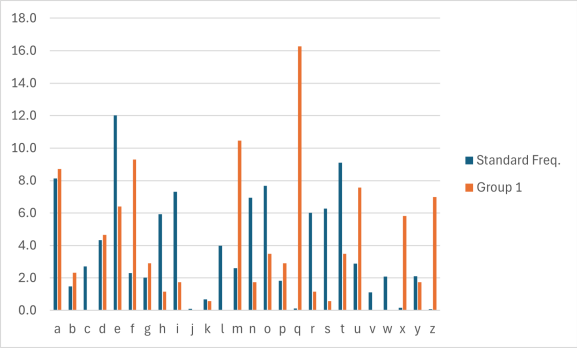

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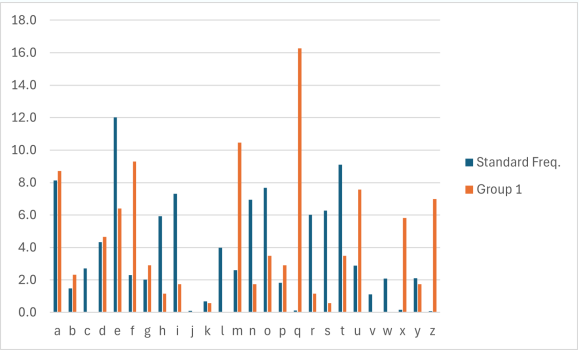

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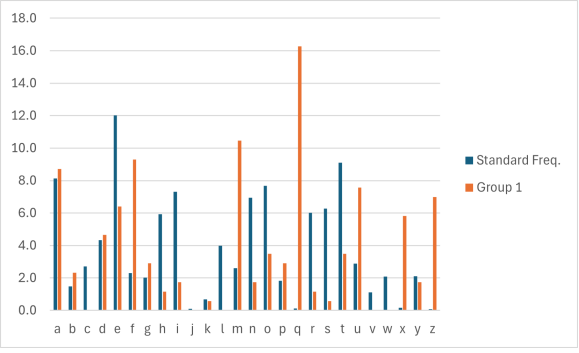

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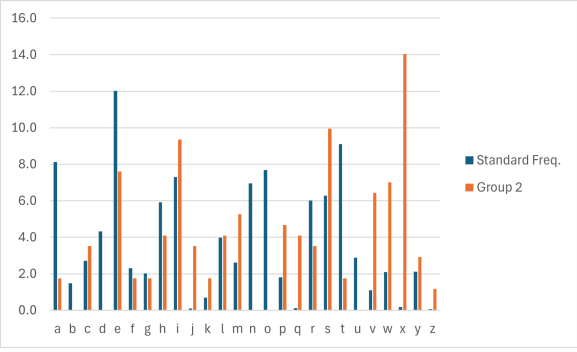
- We can find this same gap, or other patterns, and deduce that the likely shift is a to `m`: shift value 12.

Letter Group 2



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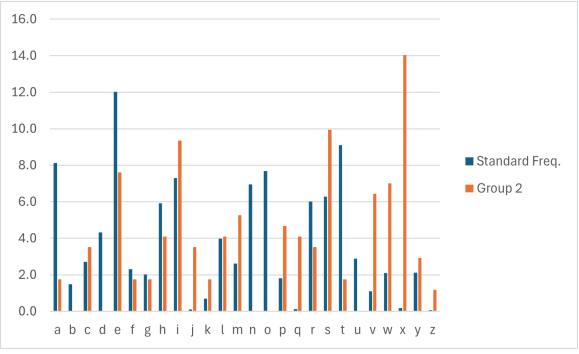

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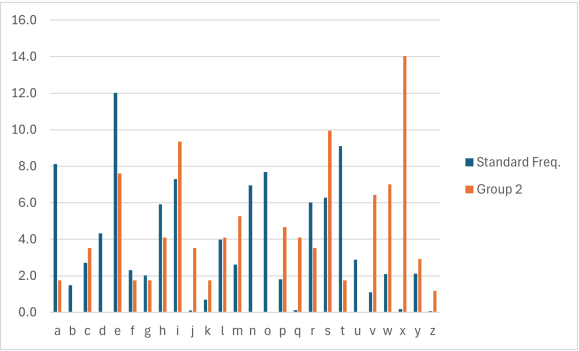

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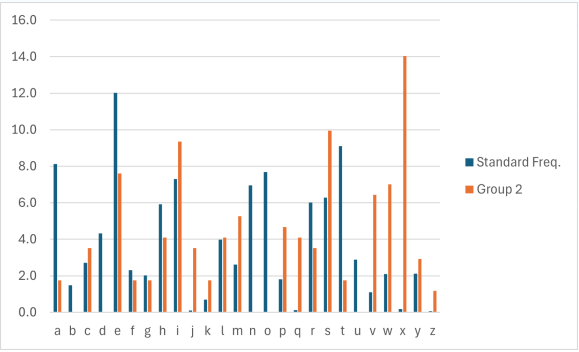

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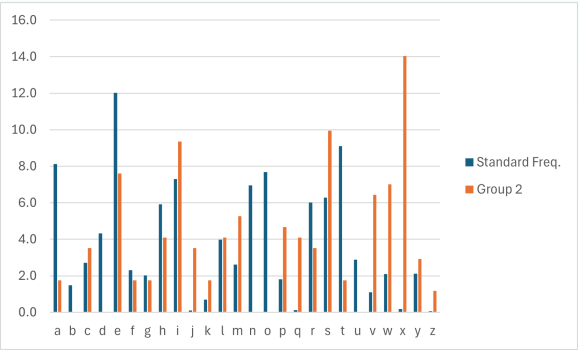

- Each group has been shifted by the same value: a Caesar cipher.
- The charts will look the same, just shifted by a number of places.
- There looks to be a gap like before from `s` to `x`, but the gap is 5 so can't be the gap from `a` to `e`.
- Instead we can choose the gap `e` to `i` and deduce that the likely shift is `a` to `e`: shift value 4.

Other Letter Groups

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- So the keyword appears to be `meteor` and we can then attempt to decrypt the text.

noonewouldhavebelievedinthelastyearsofthenineteenthcenturythatthisworldw
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dperhapsalmostasnarrowlyasamanwithamicroscopemightscrutinisethetransientcreatu
sthatswarmandmultiplyinadropofwaterwithinfinitecomplacencymenwenttoandfroovert
sglobeabouttheirlittleaffairssereneintheirassuranceoftheirempireovermatteritis
ssiblethattheinfusoriaunderthemicroscopedothesamenoonegaveathoughttotheolderwo
dsofspaceassourcesofhumandangerorthoughtofthemonlytodismisstheideaoflifeuponth
asimpossibleorimprobableitiscurioustorecallsomeofthementalhabitsofthosedeparte
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elvesandreadytowelcomeamissionaryenterpriseyetacrossthegulfofspacemindsthatare
ourmindsasoursaretothoseofthebeaststhatperishintellectsvastandcoolandunsympath
icregardedthisearthwithenviouseyesandslowlyandsurelydrewtheirplansagainstus

noone would have believed in the last years of the nineteenth century that this world was being watched keenly and closely by intelligences greater than mans and yet as mortal as his own that as men busied themselves about their various concerns they were scrutinised and studied perhaps almost as narrowly as a man with a microscope might scrutinise the transient creatures that swarm and multiply in a drop of water with infinite complacency men went to and fro over this globe about their little affairs serene in their assurance of their empire over matter it is possible that the infusoria under the microscope do the same noone gave a thought to the older worlds of space as sources of human danger or thought of them only to dismiss the idea of life upon them as impossible or improbable it is curious to recall some of the mental habits of those departed days at most terrestrial men fancied there might be other men upon mars perhaps inferior to themselves and ready to welcome a missionary enterprise yet across the gulf of space minds that are to our minds as ours are to those of the beasts that perish intellects vast and cool and unsympathetic regarded this earth with envious eyes and slowly and surely drew their plans against us

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- This gives repeated strings of letters in the ciphertext.
- This forms the basis of a **Kasiski attack**.
- Longer messages are more likely to yield to such an attack as there will be more repeated segments.

Breaking Vigenère

ZSHRSNAYEHVRHIUIZZQZXHWEFLXPOJFCXEFJAJMLSEURXXSVZXAGSEFYKCHYMXMLWJISKPRN
MWUIWESATXQYQHDISEXCTRRTXSLIZPNCBRHVXPBKSEOILKFVMXXVHYMRFEBJMRWCSKMWFSFK
MPTWVZESPRHYMXTWAVZFNWWVPXAIAJQPOIGRNSNXHYQMKZOIUSNWQFZGXVBJFLXCKVDILGFL
FMGMGVPEGHGKGHBIRGQVAEDJMPFSGKMWGEFIAAECOJMQTRKZFLTQWTDSLGCGQQBKVKEGKYHZ
ZMLIHYQXKEBJUIGXQIQEMYFVEXAEHJIEKQOEPQNPHZBPRMBRPVHTCWIEMIFNUXAMBWURBXST
AQIPOTQRVCAVZAXRHKAEGHTIASOIFKTMLKZFNITFCLFXAIWIXMMXZVMJYEWIEWXVSEQMGXVV
UVTWGLDEGGSFRXAIWIQQIMFVAZXVARFXXVWKUWISGJUFEIHYMXMLSZZJNWCIUENRRVDXAIAZ
OVHWQFBIWSHYQWTQSEASGIURHITXVFGKAXHFFLXSZUQVPSFCPWHJGGMGXEGJAYKGSJAJAYAR
ZHTRUVDSKXVFGKAXCWFLXQCEXCMSRZEQBWGKTIBHSRAJEMTVGTHRHYQQTWWDBSLWWSXIHVWD
BVHFOSXIBXWJOYKMCLEXHVSTMPEWCDQSYXVVYIGXOCTEUMHJAJMLCJQHXTOIFIWHOPEEMQCJ
FXXVFVEXKMOCYIGJOEOMXHHYQVXQWXTXUICKTIKQSEGTHRARDWIIFYMTLMBWQVBSFKAXAIAJ
QPOIGRZHKIOUKXHASCOSFIODUWLMCEMVRIBKQVIVWJQCXXOTDSLWHYQKNPTFRWIEQVYMGHGK
TEMEFVFSHYFDURWWOJAYKWOIQXHXVFEIHJHYQFXEGKEXAEHGQVBWVZZXXPZVOXLZOJFEGHQF
APTRRLZWRQDRFLXXWTDIZEFUQHMLWJQEKXVNUXAIBMUSNWSPQWTRRJXSPPMRZHLYFVXCWVSN
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- We've narrowed it down, but that's still a lot of options.

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ZSHRSNAYEHVRHIUIZZQZXHWEFLXPOJFCXEFJAJMLSEURXXSVZXAGSEFYKCHYMXMLWJISKPRN
MWUIWESATXQYQHDISEXCTRRTXSLIZPNCBRHVXPBKSEOILKFVMXXVHYMRFEBJMRWCSKMWFSFK
MPTWVZESPRHYMXTWAVZFNWWVPXAIAJQPOIGRNSNXHYQMKZOIUSNWQFZGXVBJFLXCKVDILGFL
FMGMGVPEGHGKGHBIRGQVAEDJMPFSGKMWGEFIAAECOJMQTRKZFLTQWTDSLGCGQQBKVKEGKYHZ
ZMLIHYQXKEBJUIGXQIQEMYFVEXAEHJIEKQOEPQNPHZBPRMBRPVHTCWIEMIFNUXAMBWURBXST
AQIPOTQRVCAVZAXRHKAEGHTIASOIFKTMLKZFNITFCLFXAIWIXMMXZVMJYEWIEWXVSEQMGXVV
UVTWGLDEGGSFRXAIWIQQIMFVAZXVARFXXVWKUWISGJUFEIHYMXMLSZZJNWCIUENRRVDXAIAZ
OVHWQFBIWSHYQWTQSEASGIURHITXVFGKAXHFFLXSZUQVPSFCPWHJGGMGXEGJAYKGSJAJAYAR
ZHTRUVDSKXVFGKAXCWFLXQCEXCMSRZEQBWGKTIBHSRAJEMTVGTHRHYQQTWWDBSLWWSXIHVWD
BVHFOSXIBXWJOYKMCLEXHVSTMPEWCDQSYXVVYIGXOCTEUMHJAJMLCJQHXTOIFIWHOPEEMQCJ
FXXVFVEXKMOCYIGJOEOMXHHYQVXQWXTXUICKTIKQSEGTHRARDWIIFYMTLMBWQVBSFKAXAIAJ
QPOIGRZHKIOUKXHASCOSFIODUWLMCEMVRIBKQVIVWJQCXXOTDSLWHYQKNPTFRWIEQVYMGHGK
TEMEFVFSHYFDURWWOJAYKWOIQXHXVFEIHJHYQFXEGKEXAEHGQVBWVZZXXPZVOXLZOJFEGHQF
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MWUIWESATXQYQHDISEXCTRRTXSLIZPNCBRHVXPBKSEOILKFVMXXVHYMRFEBJMRWCSKMWFSFK
MPTWVZESPRHYMXTWAVZFNWWVPXAIAJQPOIGRNSNXHYQMKZOIUSNWQFZGXVBJFLXCKVDILGFL
FMGMGVPEGHGKGHBIRGQVAEDJMPFSGKMWGEFIAAECOJMQTRKZFLTQWTDSLGCGQQBKVKEGKYHZ
ZMLIHYQXKEBJUIGXQIQEMYFVEXAEHJIEKQOEPQNPHZBPRMBRPVHTCWIEMIFNUXAMBWURBXST
AQIPOTQRVCAVZAXRHKAEGHTIASOIFKTMLKZFNITFCLFXAIWIXMMXZVMJYEWIEWXVSEQMGXVV
UVTWGLDEGGSFRXAIWIQQIMFVAZXVARFXXVWKUWISGJUFEIHYMXMLSZZJNWCIUENRRVDXAIAZ
OVHWQFBIWSHYQWTQSEASGIURHITXVFGKAXHFFLXSZUQVPSFCPWHJGGMGXEGJAYKGSJAJAYAR
ZHTRUVDSKXVFGKAXCWFLXQCEXCMSRZEQBWGKTIBHSRAJEMTVGTHRHYQQTWWDBSLWWSXIHVWD
BVHFOSXIBXWJOYKMCLEXHVSTMPEWCDQSYXVVYIGXOCTEUMHJAJMLCJQHXTOIFIWHOPEEMQCJ
FXXVFVEXKMOCYIGJOEOMXHHYQVXQWXTXUICKTIKQSEGTHRARDWIIFYMTLMBWQVBSFKAXAIAJ
QPOIGRZHKIOUKXHASCOSFIODUWLMCEMVRIBKQVIVWJQCXXOTDSLWHYQKNPTFRWIEQVYMGHGK
TEMEFVFSHYFDURWWOJAYKWOIQXHXVFEIHJHYQFXEGKEXAEHGQVBWVZZXXPZVOXLZOJFEGHQF
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Breaking Vigenère

sequence	interval	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
XAIA	288	X	X	X		X		X	X			X				X
FLX	60	X	X	X	X	X				X		X			X	
HYQ	108	X	X	X		X			X			X				
XVF	54	X	X	X		X			X			X				
YMX	96	X	X	X		X		X				X				X
KAX	54	X	X	X		X			X			X				
FXXV	258	X	X			X										

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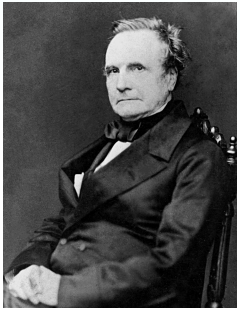
- Key lengths of 2, 3 or 4 are quite short, so we rule them out. (We may have to come back to them.) The key length is likely to be 6 and as we found out, the actual keyword was `meteor`.

Who broke the unbreakable cipher?



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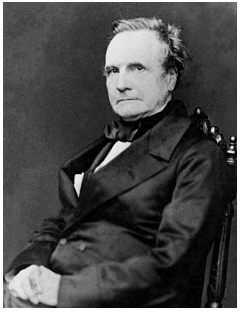

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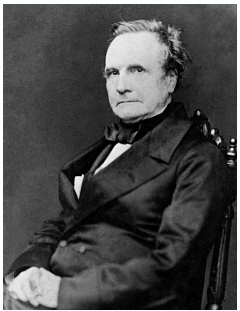

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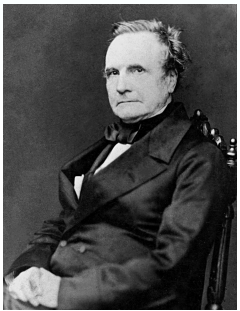

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- But Charles Babbage had cracked it in 1854. The British government wanted to keept it secret in the Crimean War.
- We know Babbage better as being the originator of the programmable computer, having designed the Analytical and Differences Engines.

Tutorials

In the tutorial this week we will:

- Create a spreadsheet to perform Vigenère encryption.
- Use a premade spreadsheet to perform a Kasiski-style attack on Vigenère encryption.