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Using Python and Flask to build a web-based cipher

Computer Science - Mini-placement research week
16-20 June 2025

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Day 1

A bit about me

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School of Computer Science and Mathematics

- **Marco Ortolani**
  - I got my PhD in Computer Engineering from the University of Palermo (Italy) in 2004
  - In 2017 I was a visiting researcher under a Fulbright grant at the Missouri University of Science and Technology,
  - and in March 2019 I joined Keele University
- My research interests regard
  - intelligent data analysis, machine learning, and knowledge discovery,
  - applications to big data analysis, security, and pervasive systems
- In particular, I'm interested in:
  - **interpretable** machine learning
  - bias, fairness and **ethical issues** in AI

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Outline – day 1

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- Intro: Using Python and Flask to build a web-based cipher
- Caesar cipher
- Setup git account
- Show app

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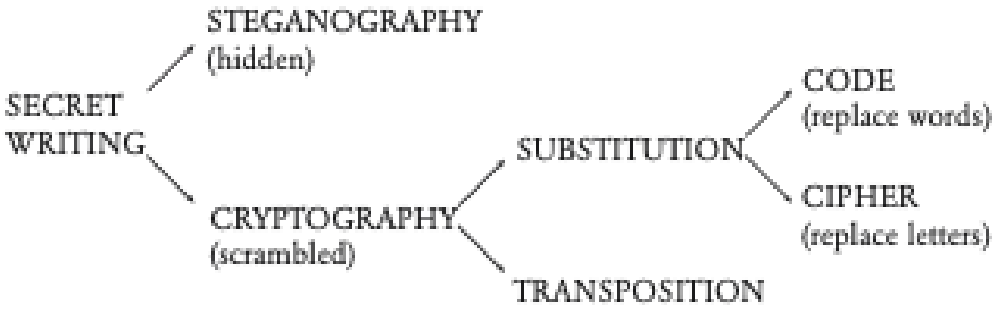
The science of secret writing



From: Singh, S., 2002. *The Code Book: How to Make It, Break It, Hack It, Or Crack it*. Delacorte Press.

Watermark videos

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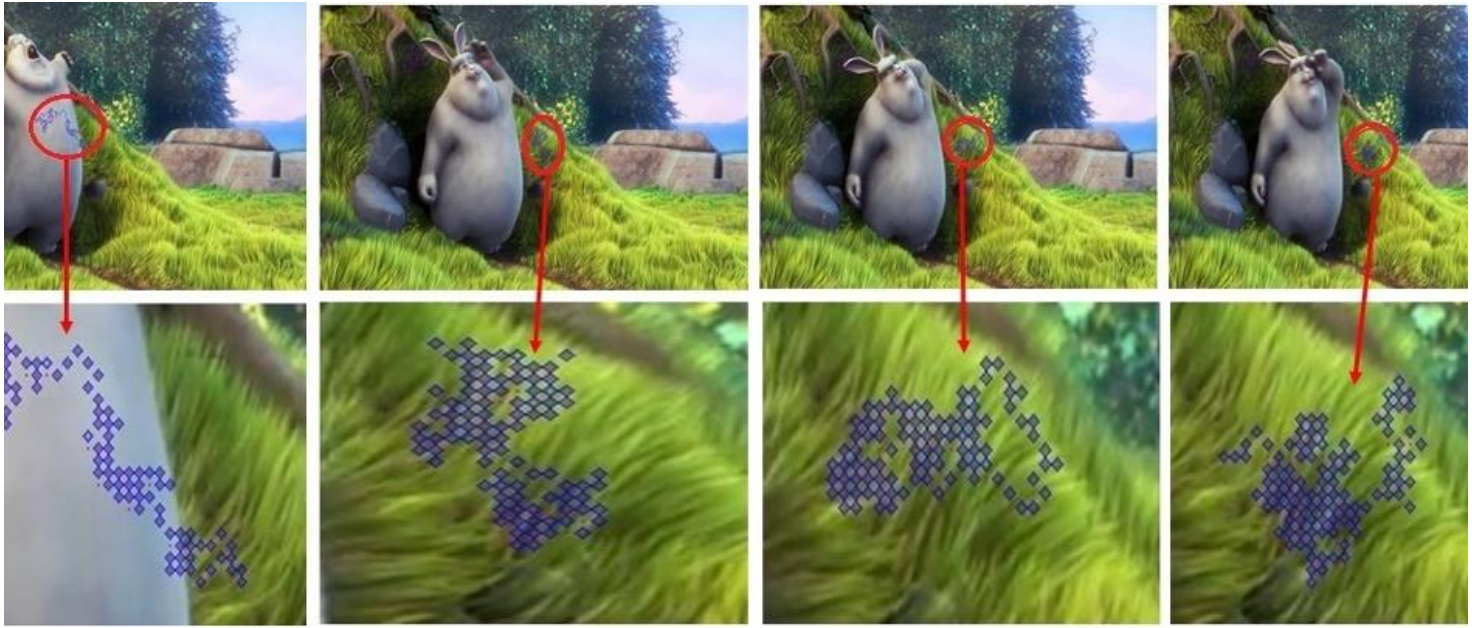

Unchangeable Video Content (Steganography)
Project by Dr Nadia Kanwal

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Encryption and ciphers

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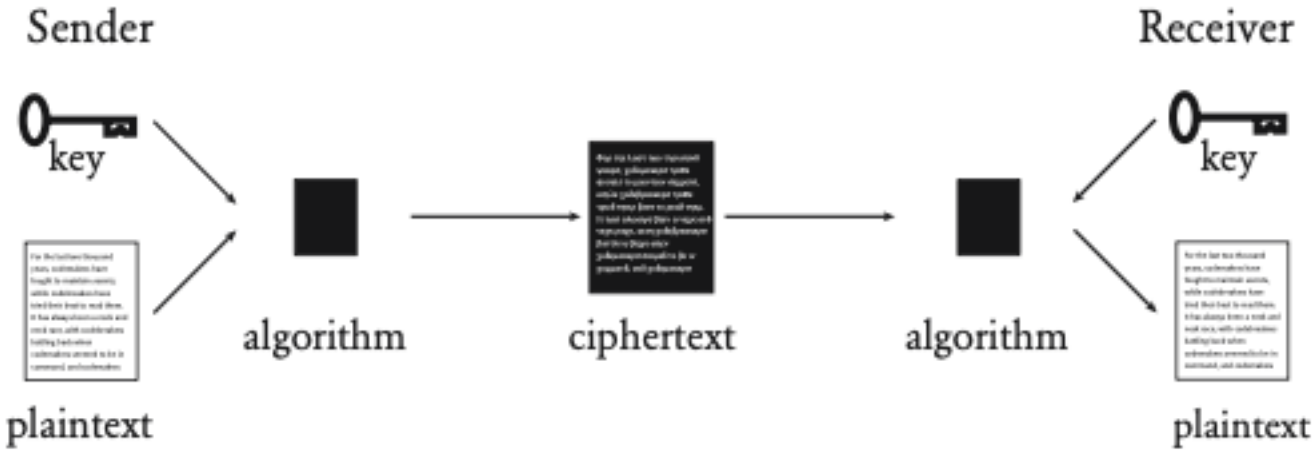
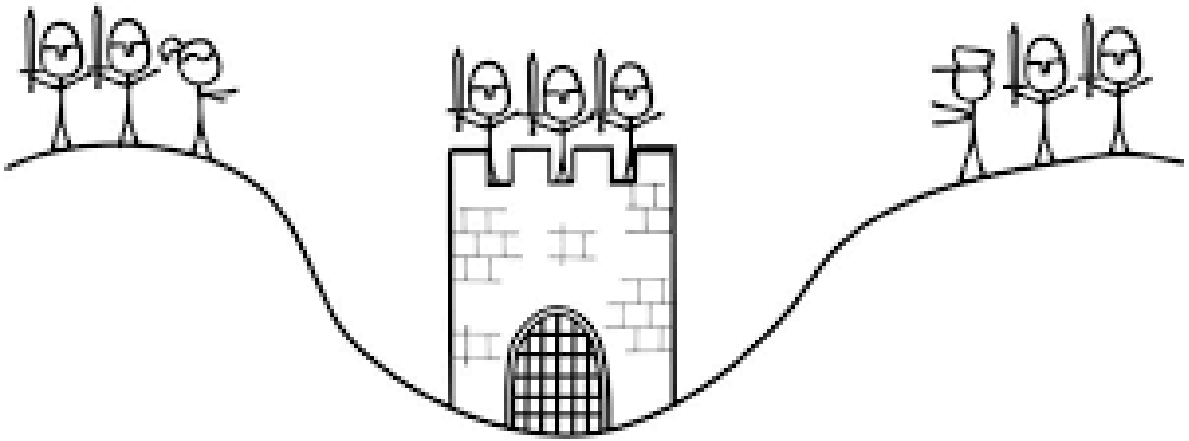


From: Singh, S., 2002. *The Code Book: How to Make It, Break It, Hack It, Or Crack it*. Delacorte Press.

Communicating over insecure channels



The two generals problem

Work

6p99472x96-5000.app.github.dev

Codes and secrets 🔐 on GitHub Codespaces and Flask

Edit `templates/index.html` or `vigenere.py` and refresh to see your changes!

Enter your text

This is a test

Encrypt Decrypt Clear

Processed text

Llkj ml s xgjx

Class activity

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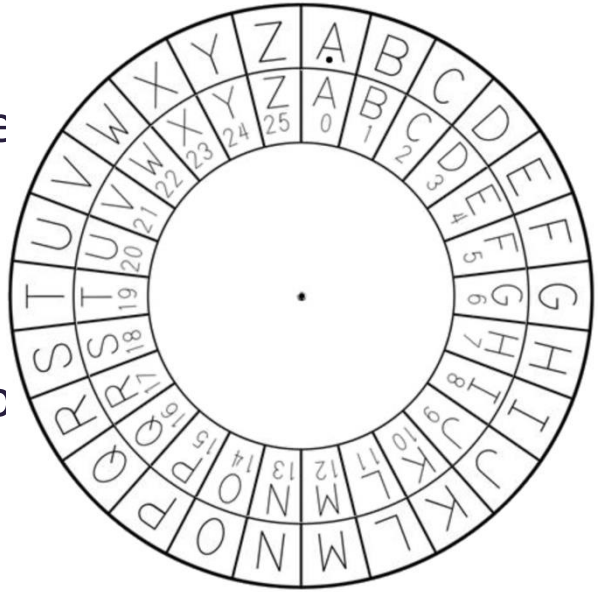
- Use your cipher wheel to try and decrypt a given ciphertext
- The wheel uses a “key” to encrypt (a numbe
  relative positions of the two wheels)
- Your tasks consists in guessing the key, so yo
  text



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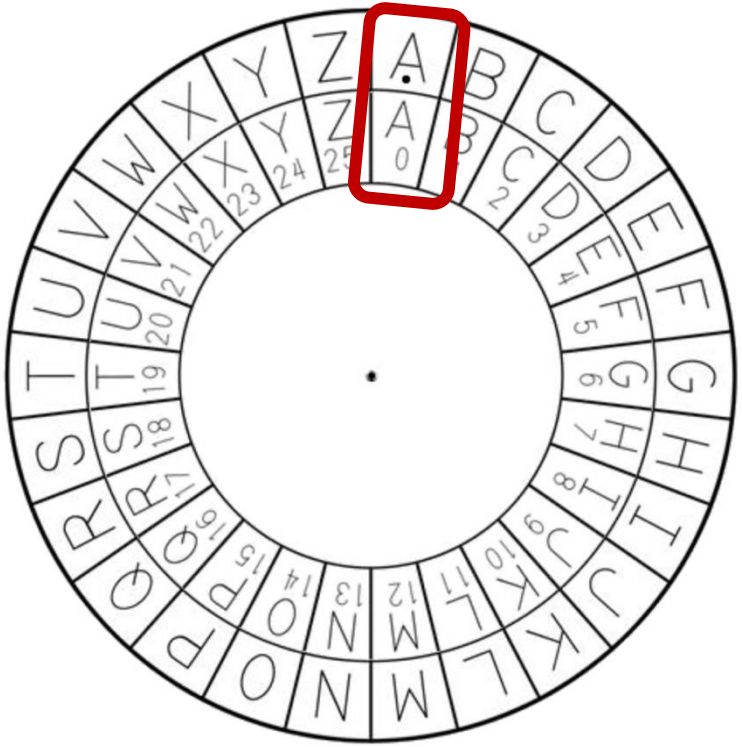
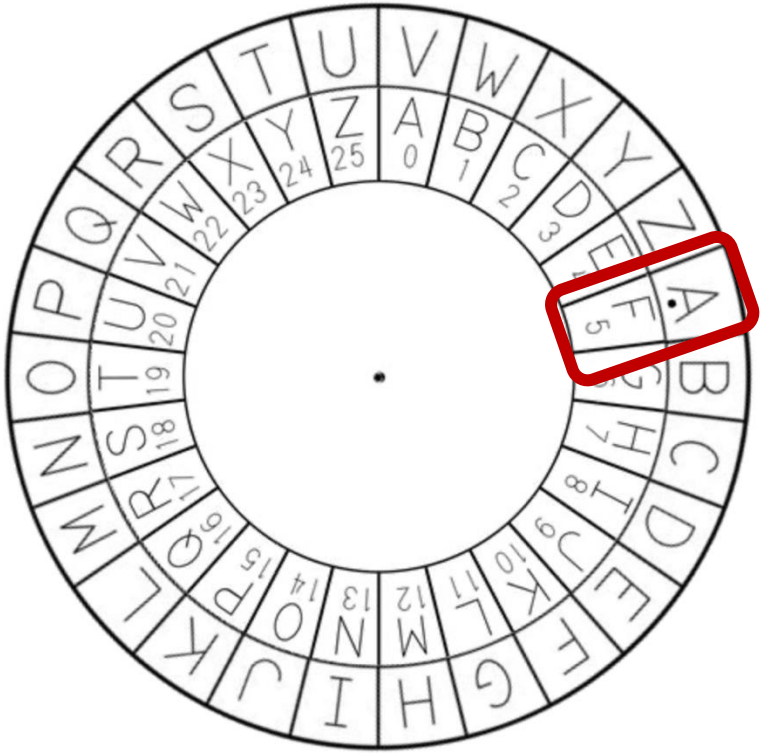
Class activity

- For instance, key=0 means no shift
  - ciphertext will be the same as cleartext



Class activity

- key=1 means shifting the external wheel so that A corresponds to
  - ciphertext will be the same as cleartext



Class activity

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- Ciphertext

SZERMT UFM DRGS XLWVH ZG PVVOV

Some extra material

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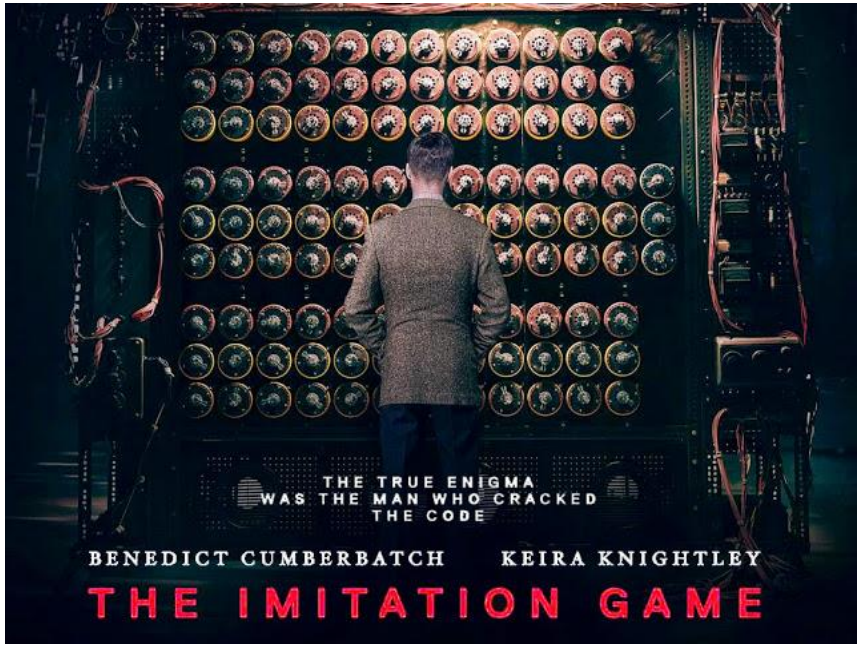
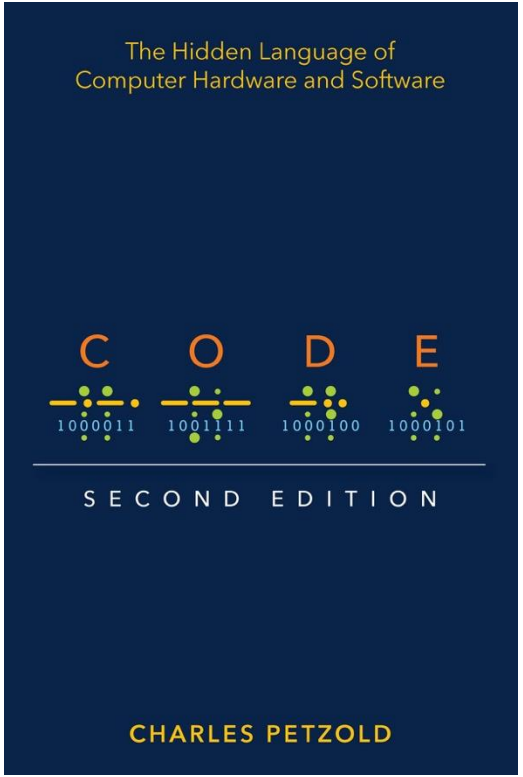
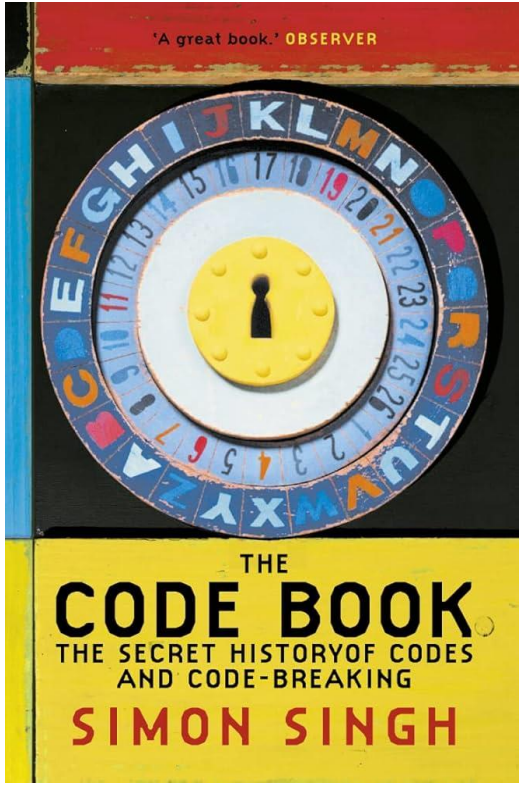


Some extra material





Activity

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- Go to: https://github.com and create an account (if you don't have one already)
  - You can also sign up for the Student Developer Pack

    https://education.github.com/pack
- Read Chapter 1 from The code book
- Decrypt

SZERMT UFM DRGS XLWVH ZG PVVOV

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Day 2

Outline – day 2

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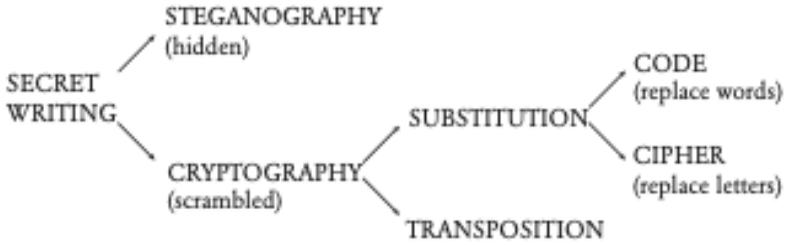
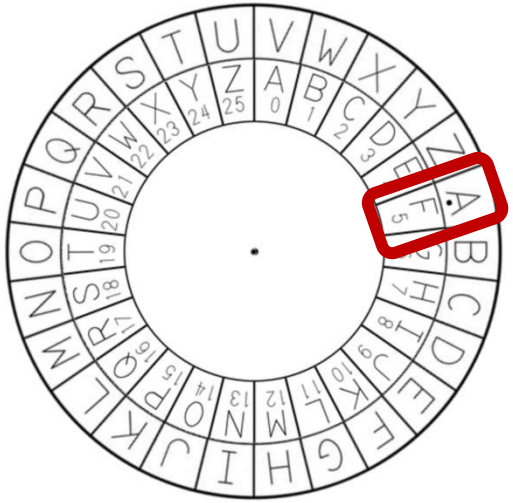
- Recap on ciphers
- Vigenère cipher
- Breaking the Babington Plot

Substitution ciphers

- Caesar's cipher is a substitution cipher





Substitution ciphers

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- Caesar's cipher is a substitution cipher

Plain alphabet	a b c d e f g h i j k l m n o p q r s t u v w x y z
Cipher alphabet	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

Plaintext	i came, i saw, i conquered
Ciphertext	L FDPH, L VDZ, L FRQTXHUHG

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Substitution ciphers

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- Ciphertext

```
SZERMT UFM DRGS XLWVH ZG PVVOV
```

- Plaintext (using “our” wheel)

```
***** *** **** ***E* ** *EE*E
```

- V -> E

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Substitution ciphers

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- Ciphertext

  SZERMT UFM DRGS XLWVH ZG PVVOV

- Plaintext (using “our” wheel)

  HAVING FUN WITH CODES AT KEELE

- V -> E (then we got the key!)

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Substitution ciphers

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- Caesar's cipher is a substitution cipher

Plain alphabet	a b c d e f g h i j k l m n o p q r s t u v w x y z
Cipher alphabet	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

Plaintext	i came, i saw, i conquered
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Substitution ciphers

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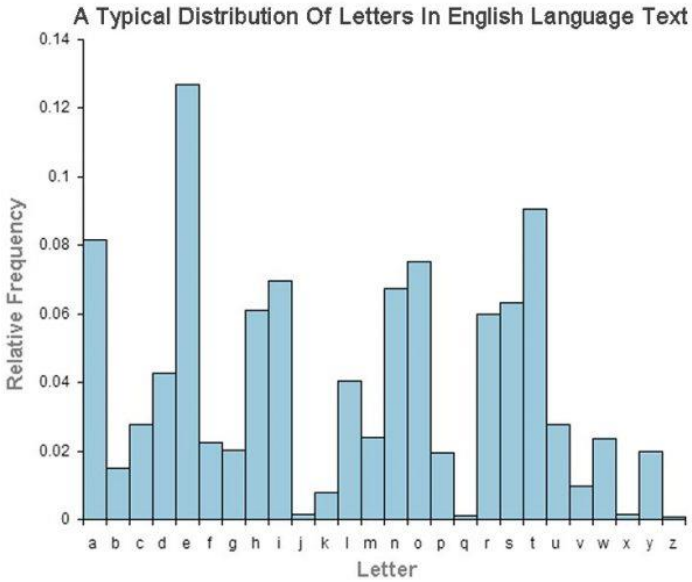
- Simple substitution ciphers are intrinsically **vulnerable** to statistical **cryptanalysis**



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Substitution ciphers

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- Ciphertext

```
SZERMT UFM DRGS XLWVH ZG PVVOV
```

- Plaintext (using “our” wheel)

```
***** *** **** ***E* ** *EE*E
```

- V -> E

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Ciphers and plots

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Mary Queen of Scots

More complex ciphers

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- Using more ciphers at the same time

Plain alphabet	a b c d e f g h i j k l m n o p q r s t u v w x y z
Cipher alphabet 1	F Z B V K I X A Y M E P L S D H J O R G N Q C U T W
Cipher alphabet 2	G O X B F W T H Q I L A P Z J D E S V Y C R K U H N

- Plaintext wheel
- Ciphertext CHKFP

Vigenère cipher

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- We can use a keyword to encode different shif for the sequence of letters in the plaintext

Plaintext	D	O	G	S
Keyword	P	E	T	S
Ciphertext	S	S	Z	K

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Vigenère cipher

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Plaintext	D	O	G	S
Keyword	P	E	T	S
Ciphertext	S	S	Z	K

- D → S
- We use “P” as the shift (P is the 16th letter of the alphabet

Vigenère cipher

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	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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Breaking Vigenère

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FHZQ US KFQ PCYZ TYYF WZJX WFPW. TYC CUVCZ MLQF FRJX IERA TYC FRRN. FHV QOOKQ IICJ OODC IHVL IE XGHE KFQ WFPP.

TYGE IJ MGR KGYE. XMP WZJX HVJB.

TYC EIXL TAJ ZQEE EUVVL ROI EAOU.

Breaking Vigenère

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Group 1: F U Q T F W T C M F I A F Q K I T I K Y H H J

Group 2: H S P Y W F Y U L R R V O Q I O V E F W E M Z

Group 3: Z K C Y Z P C V Q J Q O O C L G P P G R G W J

Group 4: Q F Y F J W Z C F X D D X H F P T I M E M X B

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Breaking Vigenère

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Group	Most Frequent Letter(s)	Frequency
1	F	4
2	R, V, F, Y, O, E	2 (tie)
3	C, P, G	3 (tie)
4	F	4

Try it out

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- See tasks
- Use code: https://github.com/marcoortolani/vigenere.git

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Day 3

Work

6p99472x96-5000.app.github.dev

Codes and secrets 🔐 on GitHub Codespaces and Flask

Edit `templates/index.html` or `vigenere.py` and refresh to see your changes!

Enter your text

This is a test

Encrypt Decrypt Clear

Processed text

Llkj ml s xgjx

The cipher server

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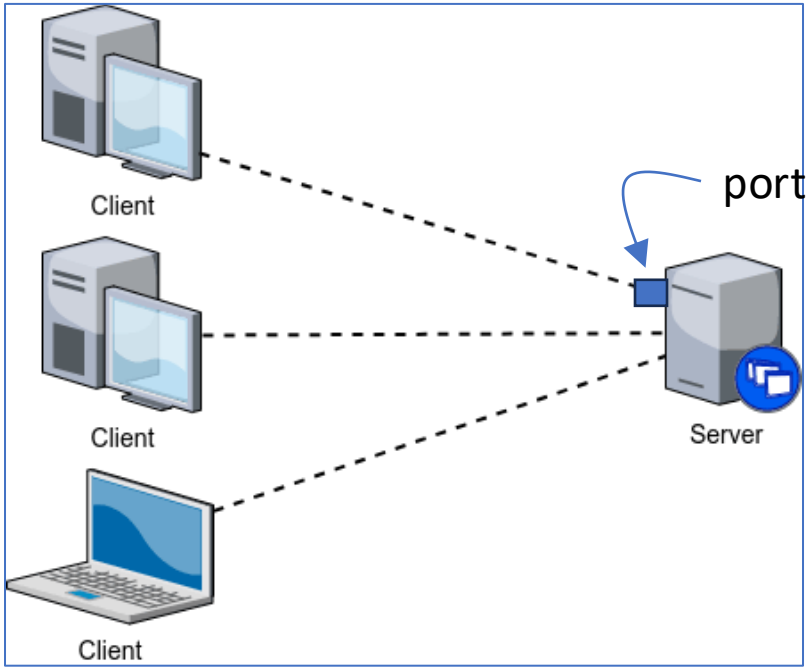

Coding the Caesar cipher

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- Loop through each character in the input text.
- If the character is a **letter**:
  - Check if it's uppercase or lowercase.
  - **Shift** it forward in the alphabet by the given number.
  - Make sure it **wraps around** (Z goes back to A).
- If it's not a letter (e.g. space, punctuation)
  - keep it the same

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Coding the Caesar cipher

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- **Key Python Features Used**
  - `char.isalpha()` → checks if the character is a **letter**
  - `ord(char)` → gets the **number code** of the character
  - `chr(number)` → gets the **letter** from the number code
  - `% 26` → wraps around the alphabet (only 26 letters)

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Activity

- Look into the `caesar_exercise.py`
- The method for encryption is implemented, but the method for decryption is not working
- Try to fix it!

Activity

- Look into the `vigenere_exercise.py`
- The method for encryption is implemented, but the method for decryption is not working
- Try to fix it!

Decrypting enemy code

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Enigma and “the bombe”

try the emulator: https://www.101computing.net/enigma-machine-emulator/

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Day 4

Suggestions for research directions

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- The Enigma machine
- The Zimmermann Telegram
- Steganography: Hiding messages in images, music, or social media posts
- Encryption: More Than Secrets — Powering Digital Signatures, Integrity & Trust
- Other ciphers:
  - One-time pad, book cipher, pigpen cipher

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Suggestions for research directions

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- Frequency analysis beyond basic letter frequency to digrams (TH, ER, IN) and trigrams (THE, AND, ING)
- The Kasiski Examination for Vigenère
- Attacking the ciphers
  - Meet-in-the-Middle Attacks
  - Chosen Plaintext/Ciphertext Attacks

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Thank you

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