Information Security
(WBCS004-05)

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Office: 0420 (Please schedule first through email)

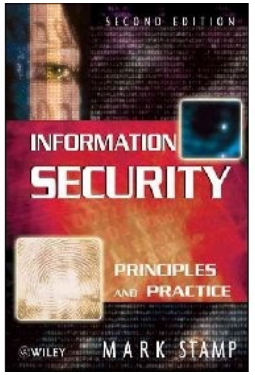
Some slides are borrowed from Dr. Frank B. Brokken and Dr. Suman Jana

Today

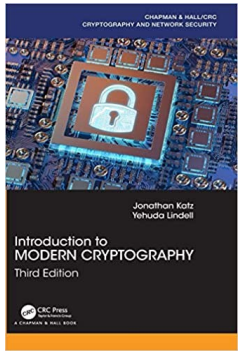
- First things first: **Logistics/Organization**
- Then
  - Introduction to Information Security
  - Crypto Basics:
    - Ceasar's Cipher,
    - Vigenere Cipher,
    - (Generalized) Substitution Ciphers
    - Transposition Cipher
  - Cryptanalysis

Books

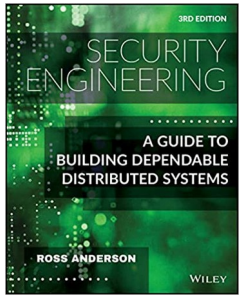
- **Information Security: Principles and Practice, 2nd Edition, 2011**



- Introduction to Modern Cryptography, Third Edition



- Security Engineering: A Guide to Building Dependable Distributed Systems, 3rd Edition



Topic overview

Week	Topic
1	Introduction + Information Security
2	Cryptography 1 (Symmetric)
3	Cryptography 2 (Asymmetric)
4	Cryptography 3 (Hashing)
5	Access Control
6	Protocols
7	Privacy
8	Software Security or PGP Practical (GPG) or Side Channels or Advanced Crypto

TBD

TAs and Communication

- Lars Andringa
- Dogukan Tuna
- Cristian Savin
- Plamen Dragiyski

- **BS** is where the Course Material will be stored and important announcements are made.
- **Discussion groups** for general questions and forming groups.
- Questions? mailto: infosec-course@rug.nl

Schedule

Week	Topic	Published (Wednesday)	Deadline (Friday, 23:59pm)	Lab/Tutorial (To be Confirmed)
6.9	Introduction			
13.9	Cryptography 1 (Symmetric)	Assignment 1		Thu (09:00 - 11:00 and 11:00 - 13:00) 2 X Fri (09:00 - 11:00)
20.9	Cryptography 2 (Asymmetric)	Assignment 2	Assignment 1	Thu (09:00 - 11:00 and 11:00 - 13:00) 2 X Fri (09:00 - 11:00)
27.9	Cryptography 3 (Hashing)	Assignment 3	Assignment 2	Thu (09:00 - 11:00 and 11:00 - 13:00) 2 X Fri (09:00 - 11:00)
4.10	Access Control		Assignment 3	
11.10	Protocols	Assignment 4		Thu (09:00 - 11:00 and 11:00 - 13:00) 2 X Fri (09:00 - 11:00)
18.10	Privacy			Thu (09:00 - 11:00 and 11:00 - 13:00) 2 X Fri (09:00 - 11:00)
25.10	Software Security or PGP Practical (GPG)		Assignment 4	

6

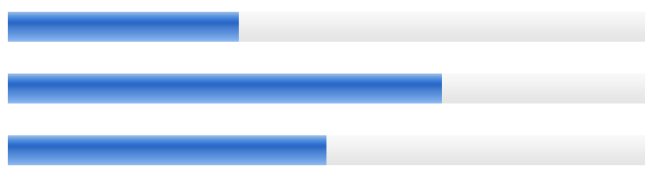
Survey Results

- Why?
  - Too many sessions
  - The attendance decreases over time
- 22 (+4) responses so far. **Complete asap…**

22 attempts have been completed

Question 1

Which lab days work for you? (**Note**: Multiple answers are possible))



Thursday, 09:00 - 11:00	8	(36.36 %)
Thursday, 11:00 - 13:00	15	(68.18 %)
Friday, 11:00 - 13:00	11	(50 %)

Thursday, 09:00 - 11:00	2	(7.69 %)
Thursday, 11:00 - 13:00	2	(7.69 %)
Friday, 09:00 - 11:00	1	(3.85 %)

Practical Assignments

- Goal: **to gain basic understanding of security and privacy by analysis and construction of theoretical concepts**

- Four (4) practical assignments
  - Content, information and deadlines **on BS**
  - No intermediate feedback!

- You will work in **groups of two or three**
  - Create groups both on BS (for grading purposes) and Themis

8

Assignment delivery

- Reports + code to **themis.housing.rug.nl**
  - Get familiar with Themis: Exchange students! Unfortunately no written tutorial is available, but we will hold a session **tomorrow (Thu 09-11)**!
  - Many submissions: We will use the latest (which should be the default behaviour)
- Solutions are to be uploaded on time! Grading penalties apply:
  - No delivery: **100%**
  - Unacceptable delivery: **100%**
  - Irregular delivery (possible): **50%**

9

Assignment delivery (cont.)

- What constitutes an *unacceptable* delivery?
  - Delivery **after** the deadline
  - **Plagiarism** of another student's answers (penalty applies to **all students involved**, disputes to be resolved by BoE)
  - **Copy/paste** from an online repository
    - Minor modifications are not accepted
    - If you inspire from a Web site, explain how you "significantly" differ from that with an additional note.
  - The submission is **unreadable** (e.g., a failing PDF)
  - The submission documents contain any items that are **scanned from notes or photographed**, e.g., no handwritten solutions will be accepted

10

Assignment delivery (cont.)

- What constitutes *irregular* delivery?
  - The files are sent by email, delayed due to miscommunication, etc.
  - Proof that the assignment was **finalized** before the deadline is required
  - Lecturers and TAs decide on acceptability

11

Corner cases

- Assignment grades can be retained for the next year max
  - **Repeating students** from last year mail us **ASAP** for the retention of grades

- Follow the rules in the Communication section of BS diligently

12

Grading

- Practical Assignments (A)
- Written Exam (E)

Final Grade (F)

```
if (A >= 5.0 and E >= 5.0) then
            F=(.6*A + .4*E)
else
            otherwise (A<5 or E<5) F=min(A,E)
```

- 6.0 is still the minimum for passing grade
- Round >*.25 and >*.75 up except for (5.25, 6) -> 6

ChatGPT/LMs, Code Assistants and others …

✓ Our goal: Teaching you the concepts!

✓ Assignments: Enforce the learning goals ⇨ The AI generators (may/will) hinder that.

➢ Therefore the use of generators is **not allowed** in the submitted answers!

- Current Policy (may change!):
  - We will strictly check the answers for AI-generated content
  - We will randomly select/contact groups for explaining their answers during the labs, that come after. We will make sure to contact the groups in time and all members are required to be present in the lab.

ChatGPT/LMs, Code Assistants and others …

Alternatives (work in progress);

- We may ask for an additional document with each assignment, that explains your writing choices and the resources used to generate the answers.

Questions about the organization?

16

What is Information Security?

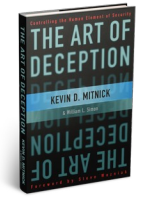
The practice of protecting information by mitigating information risks.

What is Information Security? (cont.)

What is it really in practice?

- A race between an attacker and defender?

- The “Art of Deception” [cf: Kevin Mitnick]?



- A yearly conference on ”Ethical Hacking” (i.e., hackathon)?

- …?

Different Perspectives – 1

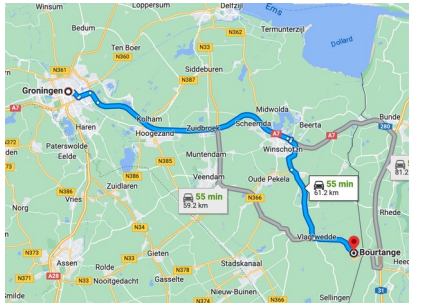
- The art of adversarial thinking

“Security requires a particular mindset. Security professionals -- at least the good ones -- see the world differently. They can't walk into a store without noticing how they might shoplift. They can't use a computer without wondering about the security vulnerabilities. They can't vote without trying to figure out how to vote twice. They just can't help it.”

- Bruce Schneier

❗ **Heard of "Harvest now - decrypt later”?**

Different Perspectives – 2



- Good Defense with Lessons Learned

- The Stronghold of Bourtange
  - Defense in depth
  - Variation of Defenses
  - A limited number of ports of entry

Where is this?

- A sentry who knows his/her stuff at critical points

Information Security: Objectives

- CIA

Information Security: Aims

- CIA
  - Confidentiality
    - unauthorized *reading* of information

Information Security: Aims

- CIA
  - Confidentiality
    - unauthorized *reading* of information
  - Integrity
    - unauthorized *writing/modification* of information

Information Security: Aims

- CIA
  - Confidentiality
    - unauthorized *reading* of information
  - Integrity
    - unauthorized *writing/modification* of information
  - Availability
    - The information/service must be available when needed

Risks of Information **In**security

- What are the risks involved when CIA is reduced or neglected?

Risks of Information **In**security (cont.)

- Confidentiality ⊆ Unauthorized Access to:
  - personnel and student records and accounts
  - medical records
  - financial information
  - access information to (computer, bank) accounts
  - e-mail
  - student progress data

Risks of Information **In**security (cont.)

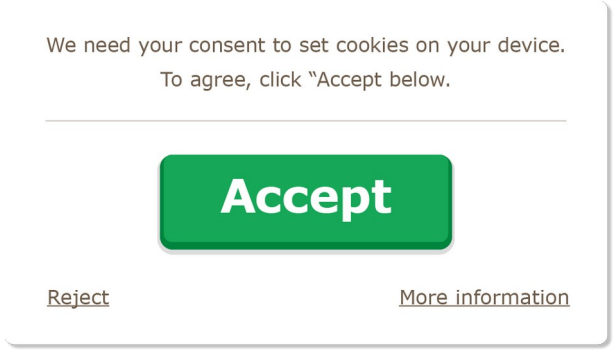
- Integrity ▭ Compromising information stored in computers:
  - legal records
  - tax information
  - financial data
  - in general: modifying information considered sensitive, confidential or secret.

Risks of Information **In**security (cont.)

- Availability ⎵ Service disruption:
  - resource blocking/stealing
  - slowed down computer or network
  - 3rd party initiated/controlled illegal activities
  - downtime, costly repairs

Legal Basis

- General Data Protection Regulation
  - cf: http://www.eugdpr.org/
  - Aim: protect all EU citizens from privacy and data breaches
    - subjects must have given their consent
    - data may only be used for intended purpose
    - no additional data may be collected
    - integrity, confidentiality are required



What is GDPR?

Legal Basis (cont.)

- EU-US Privacy Shield:

This framework protects the fundamental rights of anyone in the EU whose personal data is transferred to the United States for **commercial purposes**. It allows the free transfer of data to companies that are certified in the US under the Privacy Shield.

This was inadequate and died! Cf: https://techcrunch.com/2020/08/11/eu-us-privacy-shield-is-dead-long-live-privacy-shield / …

- Long live EU-US Data Privacy Framework (DPF)

One of the main differences between them is the emphasis on **transparency**. DPF requires participating companies to publicly disclose their privacy policies and the third-party service providers they use, and introduces new binding safeguards ensuring access by **U.S. intelligence is allowed** only to the extent necessary and proportionate … to handle/resolve complaints from Europeans … for national security purposes…

Break (10 minutes)

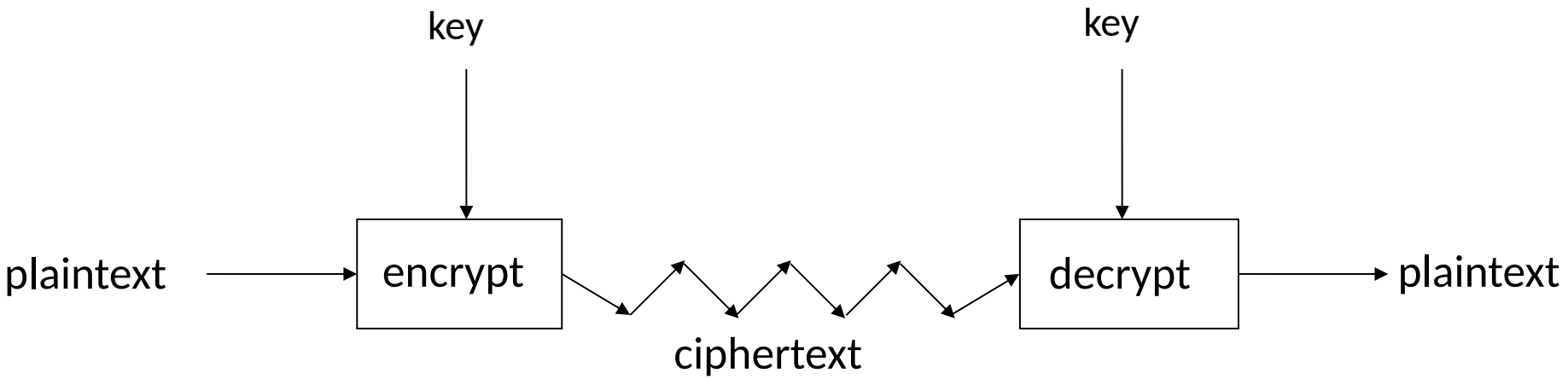
Cryptography Basics

- Classic Cryptography
  - Basics
  - Shift Ciphers (Caesar)
  - Vigenere and General Substitution cipher
  - (Double) transposition

Basics

- A *cipher* or *cryptosystem* is used to *encrypt* the *plaintext*
- The result of encryption is *ciphertext*
- We *decrypt* ciphertext to recover the plaintext
- A *key* is used to configure a cryptosystem
- A *symmetric key* cryptosystem uses the same key to encrypt as to decrypt
- A *public key (also called as "asymmetric key")* cryptosystem uses a *public key* to encrypt and a *private key* to decrypt

Crypto as Black Box



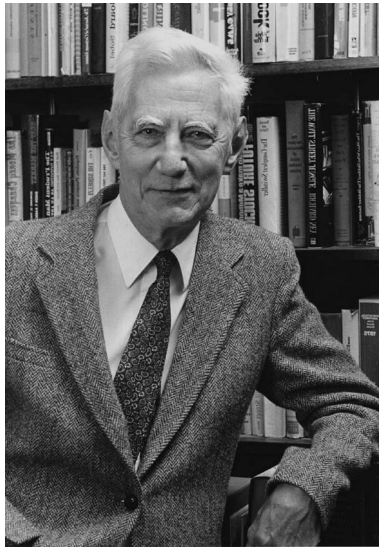
A generic view of symmetric key crypto

Principles

- Auguste Kerckhoffs (1835-1903)
  - The encryption algorithm must be **public**; the key remains **secret**.

- cf. *Journal des Sciences Militaires* Jan/Feb 1883).
- cf. *https://.../papers/kerckhoffs*.

Principles (cont.)



- Claude Shannon (1916-2001)
- Fundamental **principles** (properties for a “good” cryptosystem):
  - *confusion* (relation *plaintext – key/ciphertext* is obscure)
  - *diffusion* (spread plaintext through the ciphertext)

- Definition of secure (“information theoretic secure”)[1]:

"Perfect Secrecy" is defined by requiring a system that after a cryptogram is intercepted by the enemy the *a posteriori* probabilities of this cryptogram representing various messages be identically same as the *a priori* probabilities of the same messages before the interception.

- In practice this means: there's *no short-cut* for exhaustive search.

[1] https://pages.cs.wisc.edu/~rist/642-spring-2014/shannon-secrecy.pdf

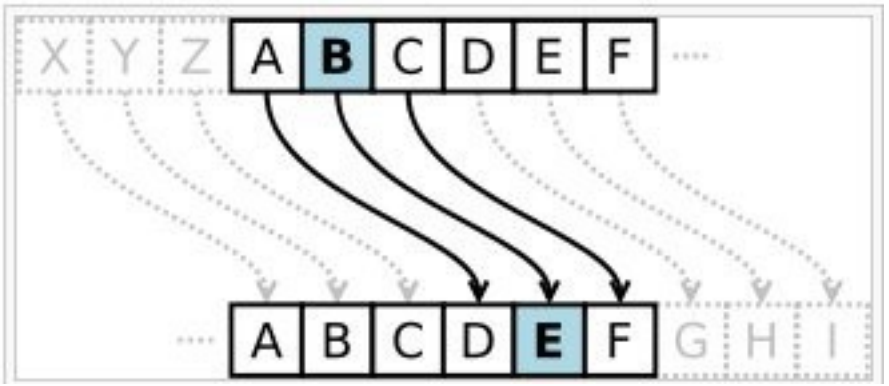
Methods vs Principles (cont.)

- Substitution: Change/replace letters
  - Uses confusion
  - Characters (‘a’ ⍾ 'p’)
  - Words (cf. the Zimmerman telegram (1917))

- Transposition: Rearrange the letters
  - Uses diffusion
  - Less strong/effective than substitution

Shift Ciphers

- Simple versions are mono-alphabetic (fixed mapping of letters)
- One of the simplest is *Caesar* cipher: substitution (of each letter) using a 3-shift



- Generalization:

To *encrypt*:
$E_n(x) = (x + n) \% 26$

To *decrypt*:
$D_n(c) = (c - n) \% 26$

Caesar Example

- Plaintext: informationsecuritycourse
- Key:

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
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

❗ Plaintext of ciphertext “TYJ”?

Cryptanalysis: Shift Cipher

Is the Shift Cipher secure?

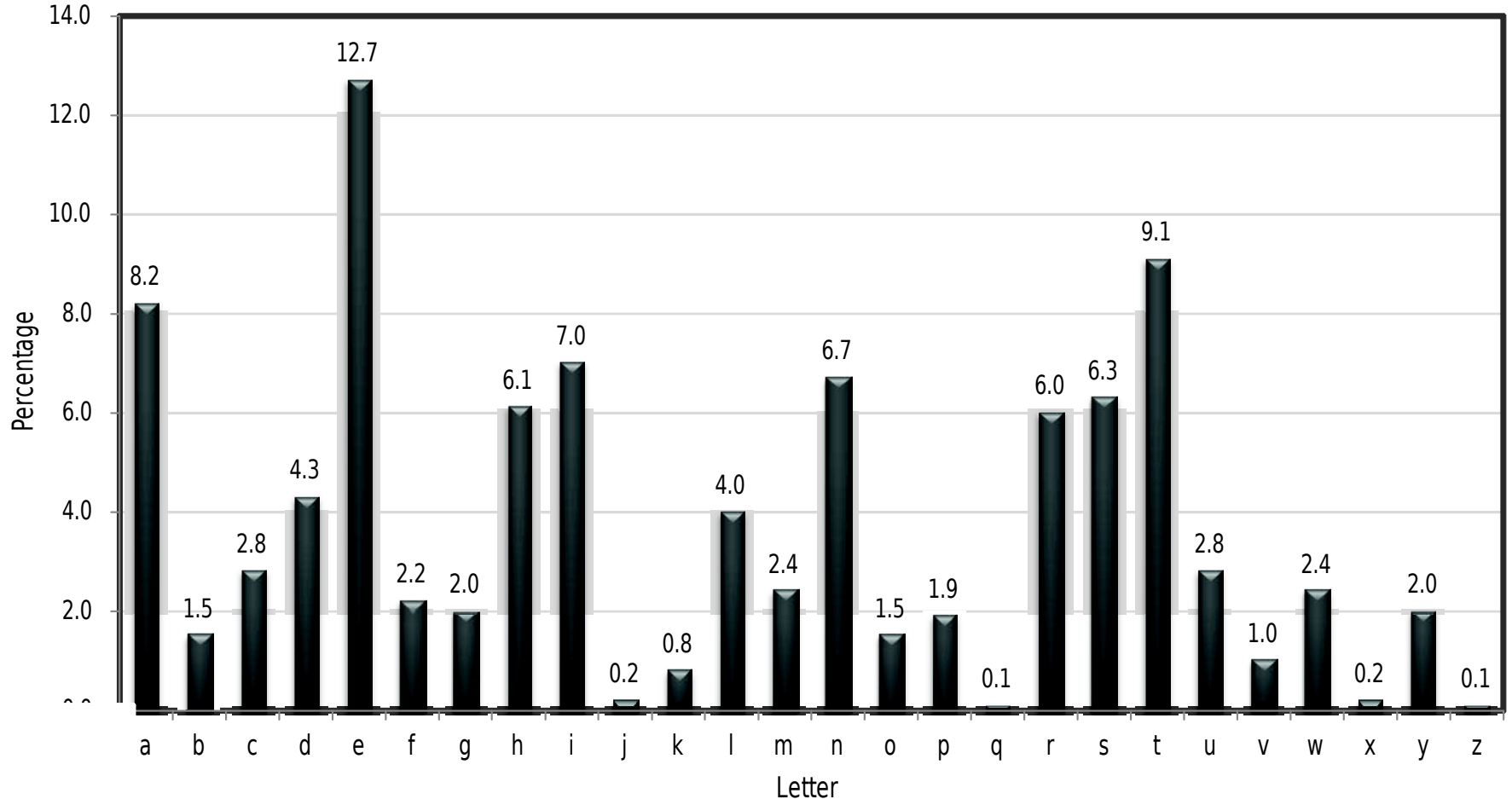
- No! Because there are 26 possible keys!
- A simple attack follows as (see the book or Katz's book for more details):
  - Given a ciphertext, try decrypting with every possible key
  - Only one possibility (of plain text) will "make sense" in the chosen language

- Example of a "brute-force" or "exhaustive-search" attack

`lipps asvph`

- khoor zruog
- jgnnq yqtnf
- ifmmp xpsme
- ?

Cryptanalysis:Using (plaintext) letter frequencies



Vigenere Cipher

- Poly-alphabetic Shift Cipher: no fixed shift value as in Caesar (e.g., 3) but varying values of shifts according to (key) letter positions
- The position (in the alphabet) of each key character represents the shift value, e.g. a =0, b=1, c=2 …
- Example, key = “cafe”, plaintext = “tellhimaboutme”

```
M: tellhimaboutme
K: cafecafecafeca
C: veqpjiredozxoe
```

If the key size is 4, what is the size of the key space?

$26^4 = 456976 \approx 2^{19}$

Attacking the Vigenère cipher

- Key length is crucial! Assume a 14-character key for example.
- **Observation**: every 14th character is “encrypted” using the same shift

```
veqpjiredozxoeualpcmsdjqu
iqndnossoscdcusoakjqmxpqr
  hyycjqoqqodhjcciowieii
```

- Looking at every 14th character

is (almost) like looking at ciphertext encrypted with the shift cipher

Borrowed from the slides of Jonathan Katz [1]

- Though a direct brute-force attack doesn’t work…
- Why not?

$26^{14} \approx 2^{66}$

Generalizing Shift Ciphers: **Substitution Ciphers**

- Generalizing Caesar's substitution cipher:
  - Do not use a fixed shift, but a permutation: plaintext letters are mapped to a ciphertext letter (mapping is the key!)
  - 26 letters allow for *26!* (*approx.* 2^{88}) *possibilities*
  - Enormous Keyspace.

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

❗ Anything wrong here?

Double Transposition

Assume the plain text: “attackatfour” and array size: 4

```
a t t a
c k a t
f o u r
```

First transposition:
permute rows from (1, 2, 3) to (3, 2, 1)

```
f o u r
c k a t
a t t a
```

```
f o u r
c k a t
a t t a
```

Second transposition: permute columns from (1, 2, 3, 4) to (4, 2, 1, 3)

```
-
 r o f u
t k c a
a t a t
```

Transposition uses the principle “”?

More on Cryptanalysis

Systematic Analysis of cryptosystems in order to decipher the messages

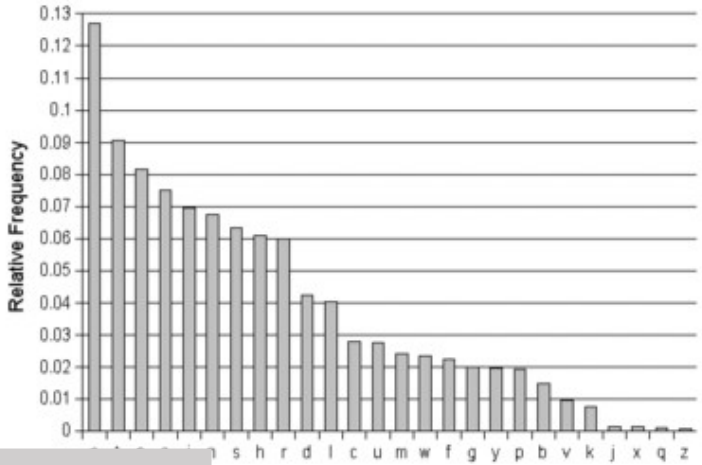
- **Ciphertext-only attack**: Trudy (the enemy) has access to the *ciphertext*, and tries to recover the *secret key* and the *plaintext*.

- **Known-plaintext attack**: Trudy knows the *plaintext* and the *ciphertext*. She tries to recover the *secret key*. This is not uncommon at all!

- **Chosen-plaintext attack**: Trudy knows the *plaintext* but she is able to choose it herself. She gets the corresponding *ciphertext*. Her target is to recover the *secret key*.
- …

More on Cryptanalysis (cont.)

- More on Language letter frequency tables:
  - Dutch: http://www.cryptogram.org/cdb/words/frequency.html
  - Other: http://codepad.clanhosts.com/index.php
    http://en.wikipedia.org/wiki/Letter_frequencies
- Techniques: anagramming, dictionary attacks…
- Large Keyspace: Sufficient key-space principle (SKSP)



Any secure encryption scheme must have a key space that is sufficiently large to make an exhaustive-search attack infeasible…

❗ Is SKSP a sufficient or a necessary condition for a secure cryptosystem?

What did we learn?

- Introduction to Information Security: *Perspectives*, *Objectives*, *Risks*
- Basic Encryption Techniques
  - Principles
  - Ceasar's Cipher,
  - Vigenere Cipher
  - (Generalized) Substitution Cipher
  - (Double) Transposition Cipher
- Cryptanalysis

References & Further Material

1. The slides of Katz & Lindell book:
   http://www.cs.umd.edu/~jkatz/crypto/s19/lectures.html

2. Web tool for classic cyphers:

https://www.dcode.fr/shift-cipher

Enough for today...

Questions