Cryptography and Security

Chapter #0: Introduction

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http://lasec.epfl.ch/

LASEC

Chapter 0: Preamble

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- Information About the Course
- Other Courses

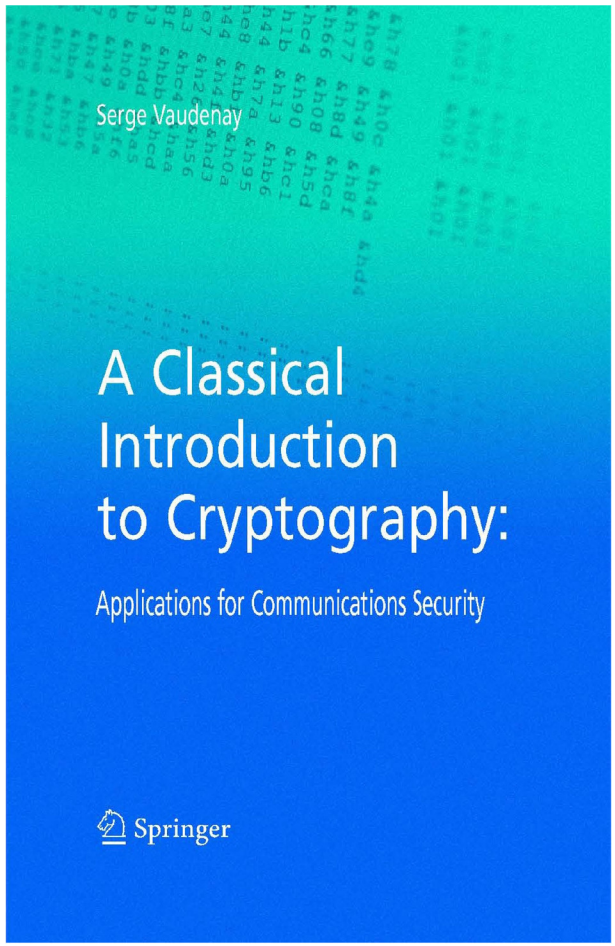
Learning Goals

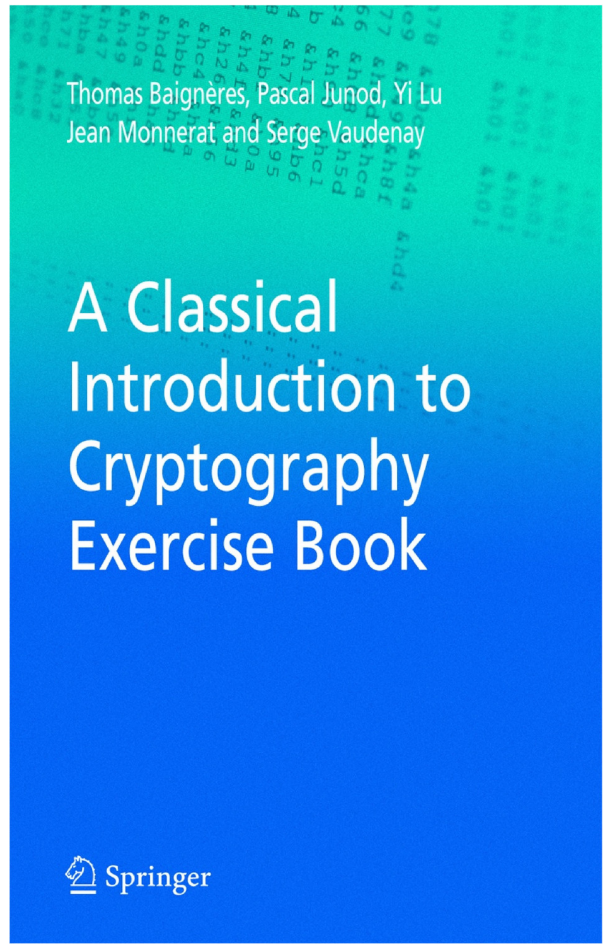
- sense of adversarial thinking
- model security problems in terms of games
- math background for public key crypto
- wide overview on the crypto domain
- key length choices

COM-401 Cryptography & Security 2025: v4.13

- This lecture has been given since 1999–2000.
- v1: complete lecture on cryptography
- v2: split basic/advanced, basic merged with network security
  lecture notes for v2 by Springer
- v3 (2008–13): less analysis, more examples
- v4 (since 2013–14): major revision
  new structure: more integrated chapters

A Classical Introduction to Cryptography

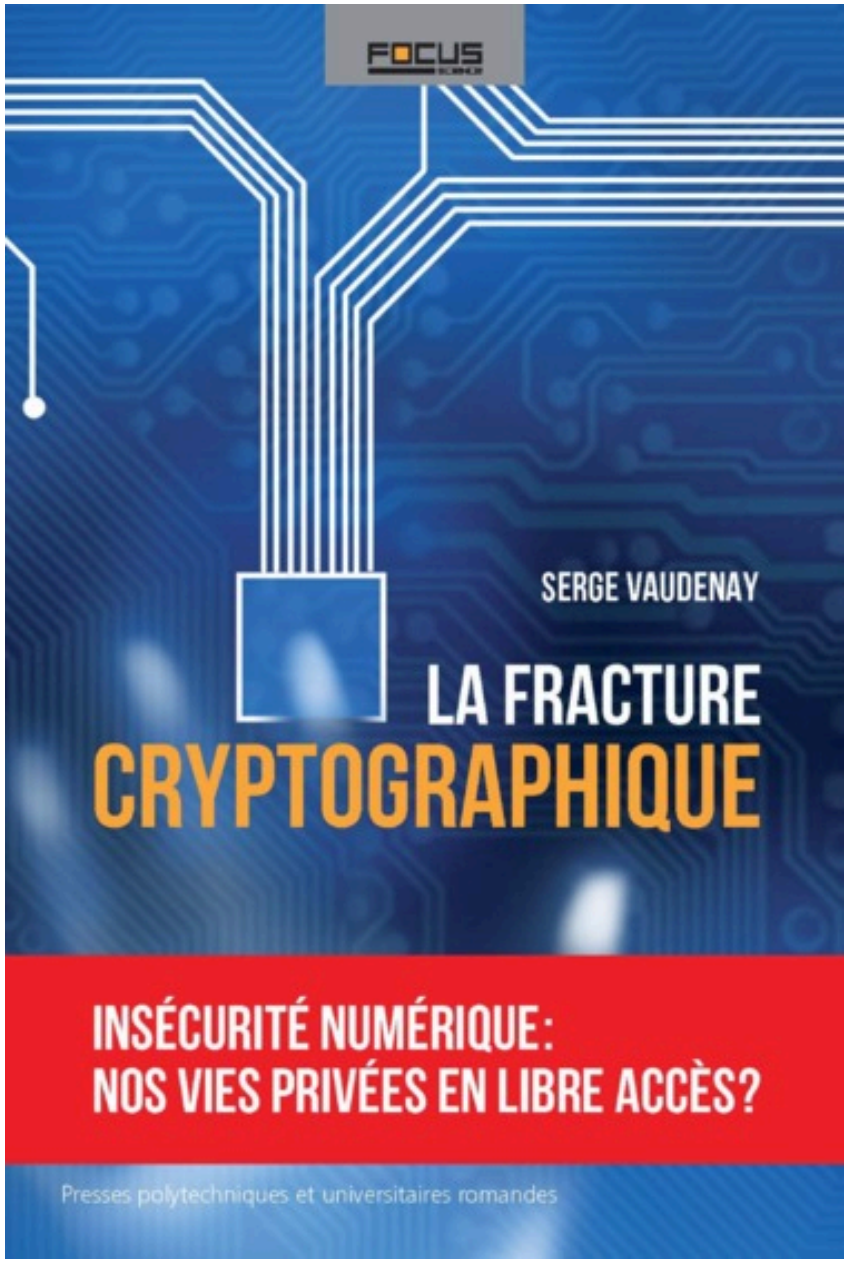




textbook exercise book

`http://www.vaudenay.ch/crypto/`

La Fracture Cryptographique



Content of this Lecture

1. **Ancient Cryptography**:
   Vigenère, Enigma, Shannon theory
2. **Diffie-Hellman Cryptography**:
   algebra, Diffie-Hellman, ElGamal
3. **RSA Cryptography**:
   number theory, RSA, factoring
4. **Elliptic Curve Cryptography**:
   elliptic curves over a finite field, ECDH, ECIES, pairing
5. **Symmetric Encryption**:
   block ciphers, stream ciphers, exhaustive search
6. **Integrity and Authentication**:
   hashing, MAC, birthday paradox
7. **Public-Key Cryptography**:
   cryptosystem, signature, pq-crypto
8. **Trust Establishment**:
   pwd-based crypto, secure communication, trust setups

++ **Case Studies**:
WiFi, Bitcoin, mobile telephony, WhatsApp, EMV, Bluetooth, biometric passport, TLS

Material

- these slides

  `http://moodle.epfl.ch/course/view.php?id=13671`

- on the web: previous exams (with solutions)

  `http://lasec.epfl.ch/courses/exams_archives.php`

- on the web: online survey trainer

  `http://lasec.epfl.ch/quizgen/quiz.html`

- Springer lecture notes (v2)

  `http://www.vaudenay.ch/crypto/`

- lecture notes (can be incomplete)
- videos (from 2020 and 2021)
- executive summary

WARNING: slides are made for students attending the course: don't even hope you can catch up by just reading the slides!

Provided Material

- presences in class is not mandatory (but recommended)
  material (slides, old video) is provided to help to catch up
- some old exercise solutions may be laconic
  do not hesitate to ask for help (TAs, forum, me)

Other References

1. **Stinson**. *Cryptography, Theory and Practice (3rd Edition).* CRC. 2005.
   Good lecture notes
2. **Menezes-van Oorschot-Vanstone**. *Handbook of Applied Cryptography.* CRC. 1997.
   `http://www.cacr.math.uwaterloo.ca/hac/`
   Reference book (not to be read from a to z)
3. **Shoup**. *A Computational Introduction to Number Theory and Algebra.* Cambridge University Press. 2005.
   `http://shoup.net/ntb`
   Textbook on algebra for cryptographers and applications.

WARNING

- lots of math in this course, including PROBABILITIES
  HOWEVER: it is not the purpose to teach math and proba
  we give “reminders”
  exercises/exams may be based on it
- mostly theory
  + a few case studies
- many topics superficially covered
  $\rightarrow$ more in Advanced Cryptography

think twice before registering to this course!

Relevant BSc Courses

mandatory:

- MATH-310 **Algebra**
- MATH 232 **Probabilities and statistics**
- CS-250 **Algorithms**

recommended:

- COM-301 **Computer security**

Prerequisites Test

- will happen on week 2 during the exercise session
- optional
- reward: grade of 4.0 or more gives a 0.5 bonus to the homework grade
- (not counted otherwise)

Schedule and Grading

lectures: Wednesday 8.15-10.00 and Thursday 10.15-12.00

exercises: Friday 9.15-11.00

midterm exam: 16.10 (closed books)

survey: about once per chapter (closed books)

$$\begin{aligned}
\text{grade} &= \operatorname*{arg\,min}_{x \in [\text{exam}-1, \text{exam}+1]} \left| x - \frac{\text{exam} + \text{continuous}}{2} \right| \\
\text{continuous} &= \text{sum}(0.4 \times \text{midterm}, 0.3 \times \text{surveys}, 0.3 \times \text{homework}) \\
\text{surveys} &= \text{average}(\text{best surveys}) && \text{3 out of 5} \\
\text{homework} &= \text{average}(\text{homework}) + \text{bonus}(\text{prereq}) && 2
\end{aligned}$$

What is this Crazy Grade Formula?

$$\text{grade} = \underset{x \in [\text{exam}-1, \text{exam}+1]}{\arg\min} \left| x - \frac{\text{exam} + \text{continuous}}{2} \right|$$

= grade from the $[\text{exam} - 1, \text{exam} + 1]$ interval which is the closest to $\frac{\text{exam}+\text{continuous}}{2}$

- if $\frac{\text{exam}+\text{continuous}}{2}$ is in the interval, this is the final grade
- if $\frac{\text{exam}+\text{continuous}}{2} > \text{exam} + 1$, the final grade is $\text{exam} + 1$
- if $\frac{\text{exam}+\text{continuous}}{2} < \text{exam} - 1$, the final grade is $\text{exam} - 1$

Your Personal Work

- attend to the lecture and take notes!
- understand the lectures, prepare for surveys
  (tip: pay special attention to slides with a red title!)
  no need to learn algorithms by heart
- work on exercises given in the exercise sessions
- do your homework
- work by yourself on past exams
- ask questions
- ask us for help if you need it

course has 8 ECTS credits:

on average, students must work $>$ 10h per week on this course

(including 3h of courses and 1.5h of exercises)

Surveys

- 10 minutes during the course (announced one week before)
- 5 multiple choice questions (4 choices per question)
- one and only one possible answer per question
- grading system

$$\text{grade} = \text{bound}_{[1,6]}\left(1 + \#\text{good answers} - \frac{\#\text{bad answers}}{2}\right)$$

- **better no answer than a bad one!**
  yes, this is harsh!
- objective:
  check that a chapter is understood
  maintain the pressure!

Homework

- in group of 2
- solving/implementing/computing exercises in **sage**
  (introduction on sage to come)
- proving

Exams

Midterm and Final Exams

- written exam with limited time
- no device such as computer, smartphone, tablet allowed
- pocket calculator allowed (and sometimes useful)
- no documents allowed (except what follows)
- 2-sided sheet of hand-written notes allowed (both exams)
- handwritten with fill-in-box forms
- look at previous exams!

How are Exams Graded

- grades are scaled based on what expected proportion of the solutions qualifies for a 4.0
- some students may exceed our expectations, ...but grades go up to 6.0 only ☺
- we do not expect students to cover all questions

we don't give the exact grading scales but all questions have the same weight

Grade Statistics — (v1) Cryptography and Security

	2001	2002	2003	2004
# students at exam	14	58	56	84
success rate	100%	90%	63%	75%
average grade	4.64	4.40	4.00	4.07
6.0	1			2
5.5	1	2	5	6
5.0	3	13	7	9
4.5	5	21	10	18
4.0	4	16	13	28
3.5		5	13	9
3.0		1	7	5
2.5				2
2.0			1	1
1.5				3
1.0				1

Grade Statistics — (v2) Cryptography and Security

	2004–05	2005–06	2006–07	2007–08
# students at exam	90	127	110	106
success rate	48%	90%	74%	85%
average grade	3.60	4.55	4.20	4.47
6.0	4	4	2	2
5.5	4	14	10	12
5.0	15	34	17	26
4.5	12	36	23	29
4.0	8	26	29	21
3.5	12	8	17	8
3.0	10	3	4	7
2.5	7	1	6	1
2.0	6	1	1	
1.5	7		1	
1.0	5			

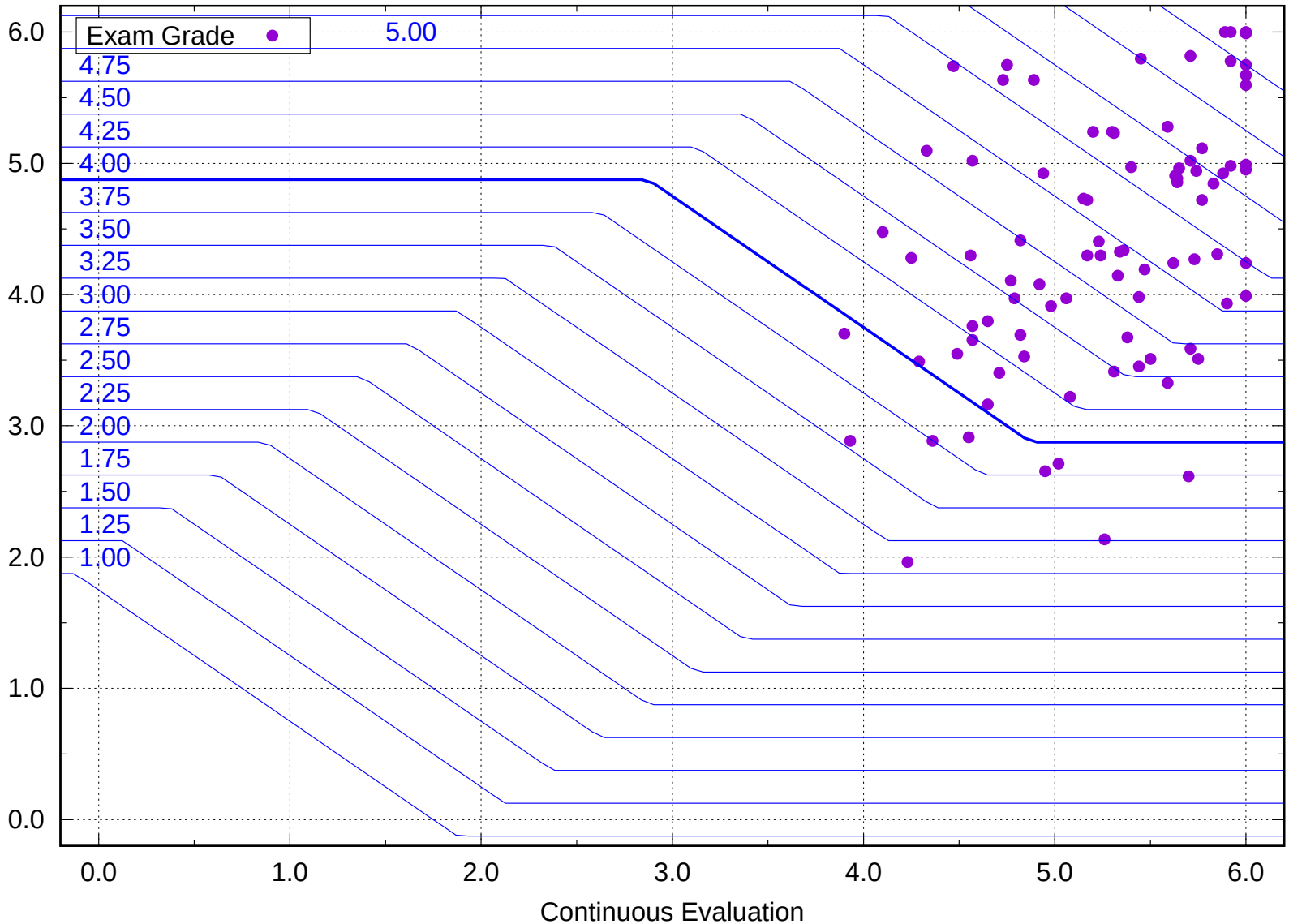
Grade Statistics — (v3) Cryptography and Security

	2008–09	2009–10	2010–11	2011–12	2012–13
# students at exam	72	41	109	107	65
success rate	81%	95%	77%	65%	72%
average grade	4.34	4.76	4.38	4.07	4.21
6.0	4	5	6	4	5
5.5	9	6	15	10	2
5.0	12	8	18	11	9
4.5	12	11	31	18	15
4.0	21	9	14	27	16
3.5	4	1	11	17	8
3.0	6	1	6	9	7
2.5	2		2	8	2
2.0	2		5	3	1
1.5			1		
1.0					

Grade Statistics — (v4) Cryptography and Security

	2013–14	2014–15	2015–16	2016–17	2017–18	2018–19	2019–20	2020–21	2021–22	2022–23	2023–24	2024–25
# students at exam	76	90	109	86	47	72	60	66	89	87	76	86
success rate	96%	95%	88%	87%	85%	90%	88%	90%	79%	75%	82%	89%
average grade	4.87	4.84	4.64	4.50	4.79	4.80	4.84	5.00	4.76	4.49	4.69	4.79
6.00	9	9	14	1	4	4	7	6	4	3	8	5
5.75				3	2	8	6	10	6	4	6	4
5.50	16	15	19	4	4	7	7	14	6	9	5	7
5.25				9	8	8	4	8	9	7	10	15
5.00	18	28	29	8	7	6	6	5	15	8	6	10
4.75				9	4	9	7	2	14	8	4	10
4.50	19	23	25	19	3	11	8	8	11	7	10	12
4.25				7	3	4	3	4	8	12	6	9
4.00	11	11	17	15	5	8	5	3	6	8	8	5
3.75				3	5	2	3		7	10	3	4
3.50	1	3	4	4	1	2		3	1	1	5	3
3.25				1		1	2	1		3		1
3.00	1			1	1	1	1		2	3	3	1
2.75				1						3		
2.50			6			1		1		1	1	
2.25				1							1	
2.00	1		1					1				
1.75							1					
1.50		1	2									
1.25												
1.00			1									

Continuous Work is Really Important!



Feedback are Valuable

- if there is something you did not understand

  $\longrightarrow$ please ask questions
- if you are lost

  $\longrightarrow$ please stop me
- if you see errors or have remarks to improve the slides

  $\longrightarrow$ please let me know
- if you have suggestion of any kind

  $\longrightarrow$ please let me know

it is counterproductive to wait until the course evaluation to give feedback!

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Specialization in ~~Information Security~~ Cyber Security - SP

course title	volume	credits	lecturer
COM-401 Cryptography and Security	56+28	8	Vaudenay
COM-402 Information Security and Privacy	42+42	8	Payer
COM-405 Mobile Networks	42+28	8	Al Hassanieh
COM-407 Advanced Networks	28+56	8	Nikolopoulos
CS-450 Algorithms II	56+42	8	Kapralov
CS-459 Foundations of Probabilistic Proofs	56+14	6	Chiesa
CS-477 Advanced Operating Systems	28+42	6	Kashyap
(CS-510 Topics in Software Security)	14+14	3	??
CS-522 Principles of Computer Systems	56+0	8	Argyraki, Candea
CS-550 Formal Verification	28+56	8	Kuncak
CS-412 Software Security	42+42	8	Payer
CS-470 Advanced Computer Architecture	42+28	8	Ienne
(MATH-489 Number Theory II.c - Cryptography)	28+28	5	Jetchev
COM-501 Advanced Cryptography	28+28	6	Vaudenay
COM-506 Student Seminar: Security Protocols and Applications	0+28	3	Vaudenay
CS-523 Advanced Topics on Privacy Enhancing Technologies	42+42	8	(vacat)

Kudelski Award

2005	**Martin Vuagnoux** AUTODAFE: an Act of Software Torture
2006	**Sylvain Pasini** Secure Communications over Insecure Channels Using an Authenticated Channel
2007	**Alexandre Karlov** Broadcast Encryption and Traitor Tracing using Elliptic Curves
2009	**Benoît Dupasquier** Encrypted VoIP Speech Recognition
2010	**Thomas Hofer** Evaluating Static Source Code Analysis Tools
2011	**Alexandre Duc** Unaligned Rebound Attack: Application to Keccak
2014	**Sylvain Heiniger** TPROXY: A Versatile Interception Proxy
	Benjamin Wesolowski Walking on Isogeny Graphs of Genus 2 Hyperelliptic Curves
2015	**Paul Bottinelli** Computational Aspects of Correlation Power Analysis Attacks
2017	**Thomas Mizraji** Extracting Cyber Threat Intelligence from the Internet Background Noise
2020	**Arnaud Pannatier** A Control Plane in Time and Space for Locality-Preserving Blockchains
2021	**Mathilde Raynal** Secure Implementation and Performance Evaluation of Post-Quantum Cryptography
2022	**Bastien Wermeille** AppSec Lifecycle Assessment
2023	**Antoine Sidem** Tapping Electromagnetic Emanations of Smartphones
2024	**Mathis Niot** Towards Optimal Trapdoors for Discrete Gaussian Sampling over Unstructured Lattices
2025	**??**

Semester Project / Master Thesis

- list of available proposals at LASEC:
  `http://lasec.epfl.ch/teaching.php`
- bring your own ideas

Student Seminar: Security Protocols and Applications

Serge Vaudenay

- (team of) students give courses on negociated topics
- written lecture notes (by the students)
- also graded by peers!
- best lectures serve as topics for the final exam

Grade Statistics — Student Seminar: SPA

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
# students at exam	10	12	28	13	13	9	13	9	9	11	13	25	15	15	9	9	11	17	26	12	21	36
success rate	100%	92%	96%	100%	100%	100%	92%	100%	100%	91%	92%	100%	93%	100%	100%	100%	100%	100%	100%	91%	100%	100&
average grade	5.45	4.58	4.73	5.23	5.15	5.39	5.08	5.06	5.44	4.86	4.73	5.28	5.60	5.08	5.56	5.19	5.34	5.54	5.74	5.25	5.92	5.90
6.00	2	1		1		3	2		1	1			9	2	5	1	1		13	2	18	29
5.75														1	1	1	2	5	6	5	2	4
5.50	6	1	6	7	6	3	4	4	6	3	5	15	4	2		1	3	10	2			
5.25														3	1	2	1	2	4			2
5.00	1	4	8	3	6	1	3	2	2	3	1	9	1			3	2					1
4.75														4	1		2		1	3	1	
4.50	1	1	8	1		2	2	3		2	3	1		1								
4.25														1	1					1		
4.00		4	5	1	1		1			1	3			1		1						
3.75																				1		
3.50			1				1				1											
3.25																						
3.00		1								1			1									
2.75																						
2.50																						
2.25																						
2.00																						
1.75																						
1.50																						
1.25																						
1.00																						

Advanced Cryptography

Serge Vaudenay

The follow up (advanced part) of this course since v3:

- more protocols: zero-knowledge, secret sharing
- cryptanalysis methods
- security analysis
- provable security

Grade Statistics — Advanced Cryptography

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
# students at exam	3	8	9	20	8	9	10	5	11	15	18	16	8	12	16	19	23	24	15	23	12
success rate	100%	88%	89%	75%	75%	89%	100%	100%	91%	93%	88%	100%	62%	75%	100%	100%	95%	87%	93%	86%	91%
average grade	4.67	4.75	5.11	4.30	4.19	4.50	4.75	5.10	5.05	4.90	4.75	4.88	4.16	4.40	4.75	5.34	5.04	4.95	4.97	4.65	4.48
6.00		3	3		3	2	2	2	4	4	3	1		1		5	1	1	2	2	1
5.75														1		3	5	2	1		
5.50			2	2					2	3	4	4		1	3	2	1	6		2	
5.25													1		2	2	4	3	2	1	1
5.00	2		1	4		1	3	1	2	2	1	5	1	1	2	3	6	3	4	4	3
4.75													1	2	2	1	3	1	2	3	3
4.50		2	2	5	1	1	1	1		2	7	2		1	3	1	1	3	2	3	
4.25																2		2		2	2
4.00	1	2		4	2	4	4	1	2	3	1	4	2	2	4		1		1	3	1
3.75													1	1				1	1	1	
3.50				3							0		1					2		1	
3.25																				1	
3.00		1	1	2		1					1		1								1
2.75														1							
2.50									1												
2.25																					
2.00										1	1			1			1				
1.75																					
1.50					2																
1.25																					
1.00																					

- Excuse me, is this the Service for asking stupid questions?