# Hashing algorithms & password cracking

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# Hash functions

# Definition

A hash function $H$ maps from data of arbitrary size (the input) to data of fixed size (the hash)

Hash functions are designed to be "one-way" (easy to compute, hard to invert)

Toy hash function:

$$y = H(x) = \lfloor 5x \bmod 10 \rfloor,\ x \in \mathbb{R} \text{ and } y \in \{0, 1, \ldots, 9\}$$

# Toy function

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$$y = H(x) = \lfloor 5x \bmod 10 \rfloor,\ x \in \mathbb{R} \text{ and } y \in \{0, 1, \ldots, 9\}$$

| $x$ | $H(x)$ |
|---|---|
| 3.14 | 5 |
| 2.72 | 3 |
| 1.41 | 7 |

**Table 1:** Input and output values

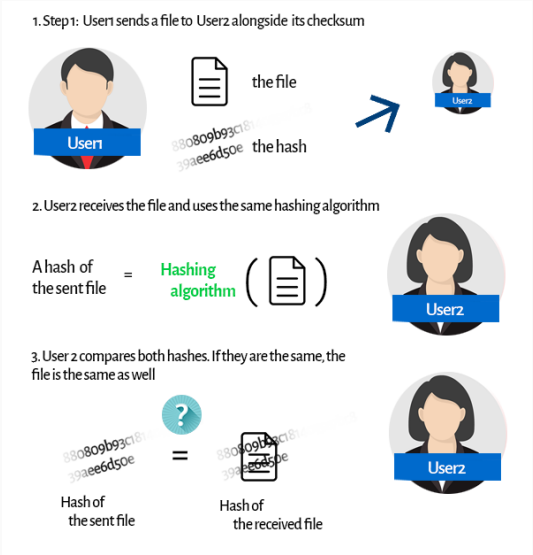
# Toy usage

- Alice & Bob are working on a homework problem
- They want to check they got the same result
- However, they do not want to reveal their answers to one-another
- Solution?

# Toy usage

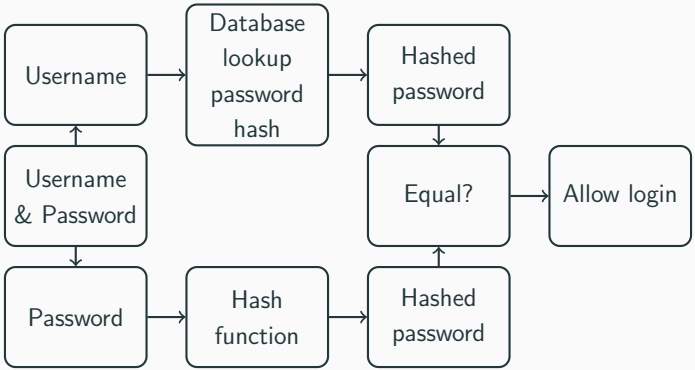
- Alice & Bob are working on a homework problem
- They want to check they got the same result
- However, they do not want to reveal their answers to one-another
- Solution? Hash and compare

# IRL usage: message authentication



# IRL usage: password verification

- Hashes are used to store passwords online
- Omits need for developers to store passwords in plaintext



# Desirable properties

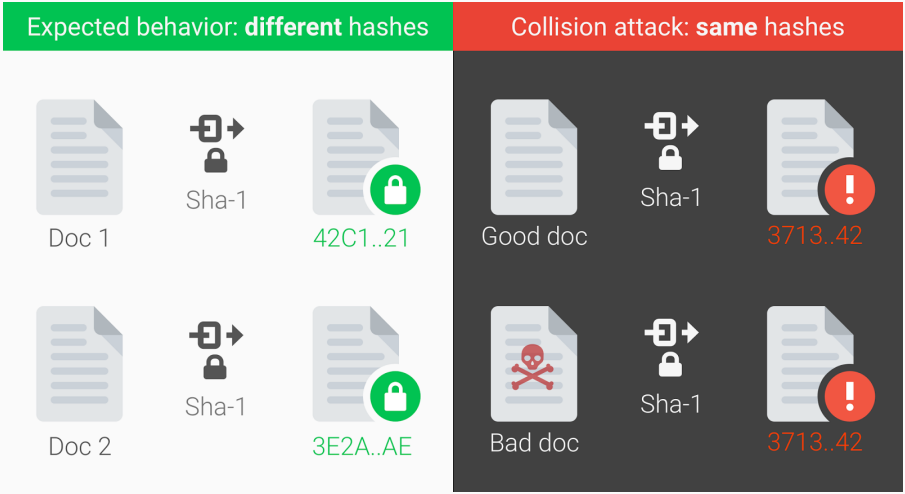
To use hash functions in the wild, we desire them to be:

1. Deterministic
2. Quick to compute given any input
3. One-way
4. Very sensitive to input
5. Infeasible to find collisions

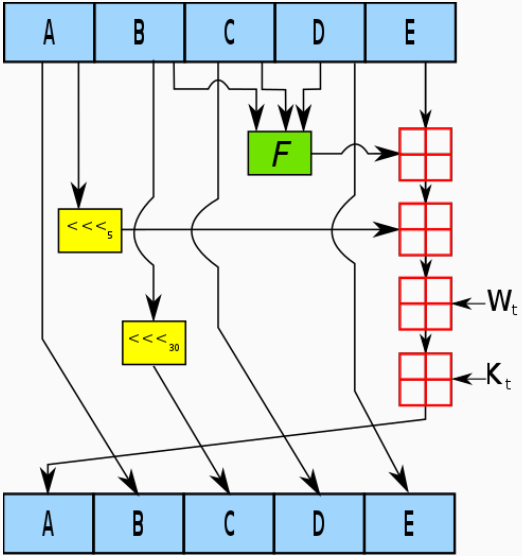
# Hashing in the wild: SHA-1

- Designed by the NSA and published in 1995
- Produces 160-bit hash (typically rendered as a hexadecimal number)
- Not considered secure against well-funded opponents (since 2005)
- In 2017 Google performed a collision attack on SHA-1

# IRL usage: message authentication



# Hashing in the wild: SHA-1



# Hashing in the wild: SHA-1

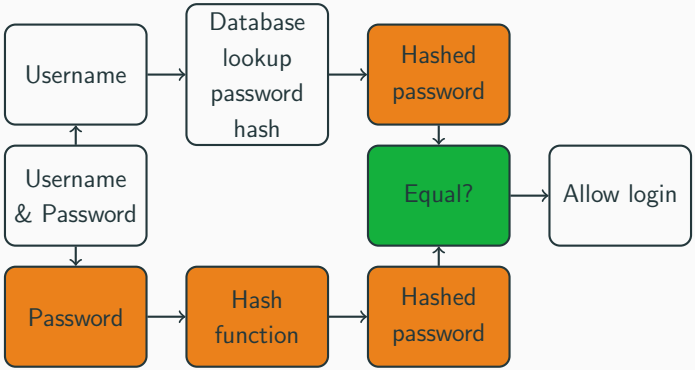
SHA1("The quick brown fox jumps over the lazy dog") output:
2fd4e1c67a2d28fced849ee1bb76e7391b93eb12

SHA1("The quick brown fox jumps over the lazy cog") output:
de9f2c7fd25e1b3afad3e85a0bd17d9b100db4b3

# Password cracking

# Hashcat

- Hashcat advertises as "World's fastest password cracker"
- Cracks passwords from leaked lists of hashed passwords
- Cracked passwords & emails used to attempt access to other services



# Demonstrations

- We will use the GPU equipped machine “Langkawi” (thanks NPP) to run hashcat
- Langkawi is equipped with a NVIDIA Tesla K40c graphics card, with 12gb onboard RAM
- Attempt to crack md5 hashed passwords released from LulzSec’s 2011 hack of EA’s Battlefield Heroes game

# Brute force demo

```
$ hashcat -m 0 -a 3 -O bfield.hash
```

# Brute force attack

| | Password length | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 6 | | | | 7 | | | | 8 | | | | 9 | | | |
| | y | d | h | m | y | d | h | m | y | d | h | m | y | d | h | m |
| 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 22 |
| 36 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 0 | 0 | 7 | 3 |
| 62 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14 | 0 | 0 | 15 | 9 | 0 | 39 | 4 | 4 |
| 95 | 0 | 0 | 0 | 3 | 0 | 0 | 4 | 50 | 0 | 19 | 4 | 42 | 4 | 363 | 15 | 19 |

**Table 2:** Worst case scenario times to crack passwords hashed with md5 on Langkawi

# Dictionary attack

- Time to crack “P@55word” is 19 days. But surely this is a weak password?
- Instead of brute force we should try words we know people have used as passwords — so called dictionary attack
- Dictionary attacks make use of ‘word-lists’: lists of leaked passwords

# RockYou list

- 'RockYou' was a company which developed widgets for MySpace.
- Hackers used a 10-year-old SQL vulnerability to get RockYou user's passwords
- RockYou used an unencrypted database to store plaintext passwords (d'oh)
- List of these plaintext passwords is easily obtainable online. Known as 'RockYou list'

# Dictionary demo

```
$ ./hashcat -a 0 -m 0 -O bfield.hash rockyou.txt
```

# Rule based attack

- One of the most complicated attack modes
- Used to manipulate and transform passwords in word-lists (like the RockYou list)
- Rule-based attack like a programming language for password candidate generation

- Why not stick to regular expressions? Too slow.
- Typically have to generate 1 billion+ password candidates in less than 10 ms

# Rule based attack

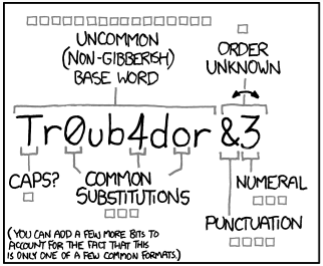
```
$ ./hashcat -a 0 -m 0 -O bfield.hash rockyou.txt -r rules/dive.rule
```

# Setting secure passwords

# Password security

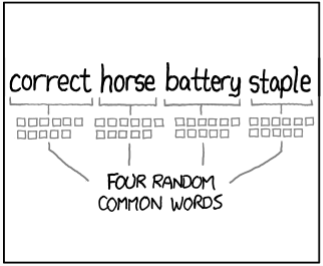
- All your passwords are bad and you should feel bad (probably)
- But how should we set secure ones?

# xkcd

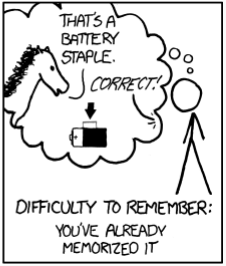

UNCOMMON (NON-GIBBERISH) BASE WORD
ORDER UNKNOWN
Tr0ub4dor &3
CAPS?
COMMON SUBSTITUTIONS
NUMERAL
PUNCTUATION
(YOU CAN ADD A FEW MORE BITS TO ACCOUNT FOR THE FACT THAT THIS IS ONLY ONE OF A FEW COMMON FORMATS.)


~28 BITS OF ENTROPY
2^28 = 3 DAYS AT 1000 GUESSES/SEC
(PLAUSIBLE ATTACK ON A WEAK REMOTE WEB SERVICE. YES, CRACKING A STOLEN HASH IS FASTER, BUT IT'S NOT WHAT THE AVERAGE USER SHOULD WORRY ABOUT.)
DIFFICULTY TO GUESS:
EASY


WAS IT TROMBONE? NO, TROUBADOR. AND ONE OF THE Os WAS A ZERO?
AND THERE WAS SOME SYMBOL...
DIFFICULTY TO REMEMBER:
HARD


correct horse battery staple
FOUR RANDOM COMMON WORDS


~44 BITS OF ENTROPY
2^44 = 550 YEARS AT 1000 GUESSES/SEC
DIFFICULTY TO GUESS:
HARD


THAT'S A BATTERY STAPLE.
CORRECT!
DIFFICULTY TO REMEMBER:
YOU'VE ALREADY MEMORIZED IT

# Passphrase generation

- Should move away from the concept of passwords to passphrases
- There are many passphrase generation techniques (DiceWare, PAO method, Schneier's Method, etc.)
- Recommend approach similar to xkcd. Additionally use uncommon words!
- Lists online of most common English words
- Don't use words or phrases that are meaningful to you

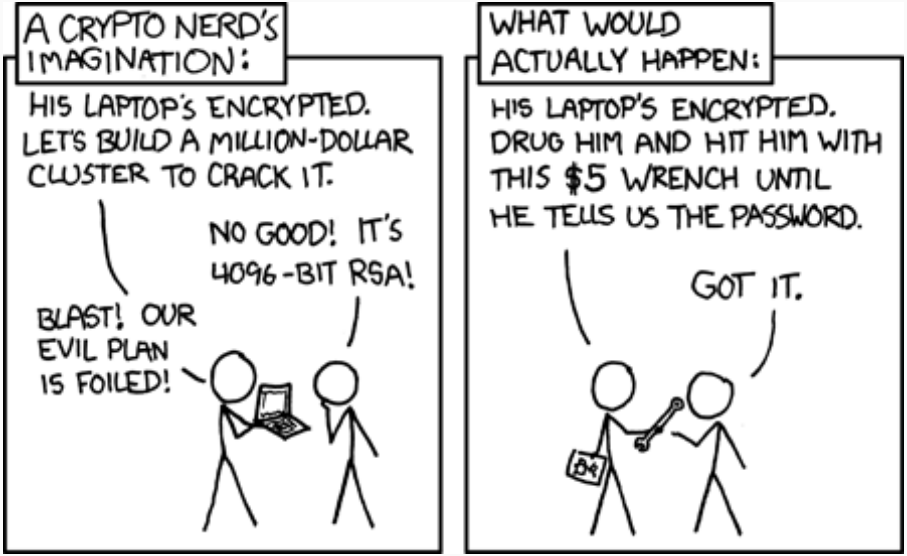
# Password managers

- Never reuse passwords
- Password managers provide an easy way to acheive this
- LastPass, 1password, KeePass, KeePassX
- With password managers the emphasis is on setting a secure master password

# Strong bois

- neon meat dream of an octafish
- murmuration cacophany
- phizzwizzwards quogwinkle

# Expectations vs. reality



# Take home points

1. Hash functions have uses in encryption and message authentication
2. Hashed passwords can be cracked using specialist software
3. Password managers help improve security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