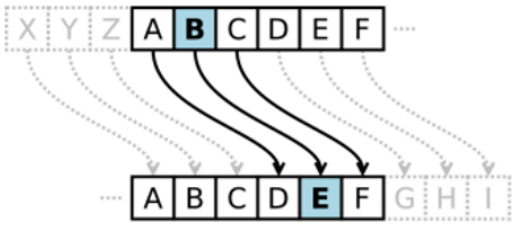
Cryptography:

Question 1: Charlie has a new startup called SecureCrypto that offers an app that provides end-to-end encryption on chat services. His app gets a lot of press as the first chat service to provide encryption. When interviewed by Wired.com about the details of how it works, Charlie says that the encryption scheme is the secret sauce of SecureCrypto, and you have to just use it to believe it. Would you download the SecureCrypto app?

- Standardized encryption schemes that anyone can use
- Easier for encryption schemes to be deployed and adopted and ensures that schemes receive public scrutiny
- Increasing our confidence in their security

Ceasar Cipher: Substitution Cipher

Plaintext letters replaced with letters fixed shift way in the alphabet.



Example:

- Plaintext: HEY BRUTUS BRING A KNIFE TO THE PARTY.
- Ciphertext: KHB EUXWXV EULQJ D NQLIH WR WKH SDUWB
- Key Shift 3:
  - ABCDEFGHIJKLMNOPQRSTUVWXYZ
  - DEFGHIJKLMNOPQRSTUVWXYZABC

The Ceasar Cipher falls in the class of substitution ciphers. In this example we see that it contains

- The state space of plaintext as the uppercase alphabet.
- The state space of ciphertext as the uppercase alphabet
- The encryption algorithm: shift the plain text right by a constant value (k)

- Key (k) generation algorithm: a value in the range of 0 - 25
- Decryption algorithm: shift the ciphertext left by the same constant value (k)

Question 2: Part A: Is it possible to launch an attack on the ceasar cipher? Construct your attack in pseudocode. What information do you need to know to launch the attack?

Bob uses the Ceasar Cipher to encyrpt his email to Alice. Here's the encrypted text.

Lm Epmgi,

Lsti csy evi aipp! Livi mw xli wigvix qiwweki M aerx xs wirh csy fijsvi ai qiix. Wii csy ribx aiio!

Fiwx,
Fsf

Question 2: Part B: What strategies can you employ other than brute force to decrypt this text?

Question 2: Part C: What lessons from the attacks we just conducted can we use to improve our cipher?

Vigenere Cipher: Key is now a string and not just a character.

Vigenère Cipher (1596)

- Main weakness of monoalphabetic substitution ciphers:
  - Each letter in the ciphertext corresponds to only one letter in the plaintext
- Polyalphabetic substitution cipher
  - Given a key $K = (k_1, k_2, \ldots, k_m)$
  - Shift each letter p in the plaintext by k_i, where i is modulo 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
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

Plaintext	CRYPTOGRAPHY
Key	LUCKLUCKLUCK (Shift 11 20 2 10 11 20 2 11 …)
Ciphertext	NLAZEIIBLJJI

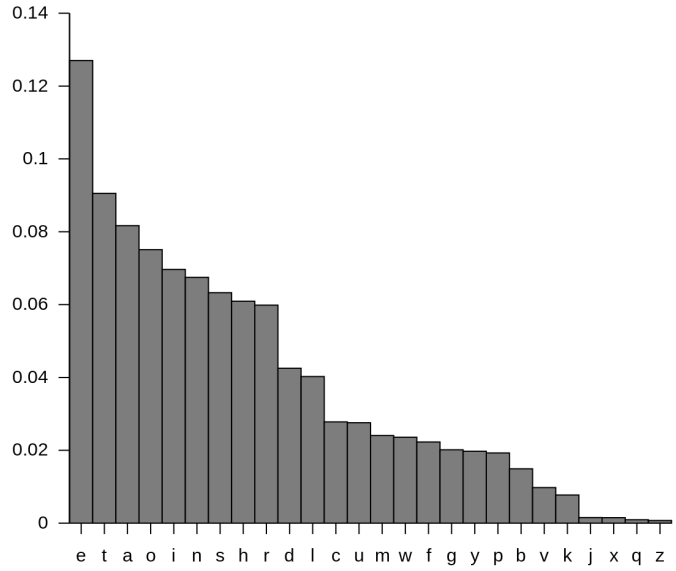
The Vigenere Cipher falls in the class of polyalphabetic substitution ciphers. In this example we see that it contains

- The state space of plaintext as the uppercase alphabet.
- The state space of ciphertext as the uppercase alphabet
- The encryption algorithm: shift the plain text right by a string
- Decryption algorithm: shift the ciphertext left by the same string.

Question 3 Part A: If we have a key of 14 characters. What is the size of the key space? Is it possible to launch a brute force attack?

Question 3 Part B: Is the Vigenere cipher secure?

What if you as the attacker know the key length - can you use this to launch a more sophisticated attack? What if you also knew the English character frequencies?



Question 3 Part C: Bob decides to send Alice a new message with the Vigenere Cipher. You know that the key is 5 letters long.
Jz Yab**e**v,

Rwb**u** tgea**g**i apg**p**fr qx **d**imzx**p**! Jct r**q**l ltq**v** nctd.

Dvqi, U**q**s

So far we have used modulo operation on characters. But this is a very limited state space. Instead, let's represent all the data we want to encrypt (email, PDFs, images, video) in bits.

For modern cryptography, we will now transform our "plaintext" to "ciphertext" using bitwise operations. The most commonly used bitwise operation in cryptography is the exclusive OR operator or XOR. Here's a review of XOR.

The XOR operator takes two bits and outputs one bit:

$0 \oplus 0 = 0$
$0 \oplus 1 = 1$
$1 \oplus 0 = 1$
$1 \oplus 1 = 0$

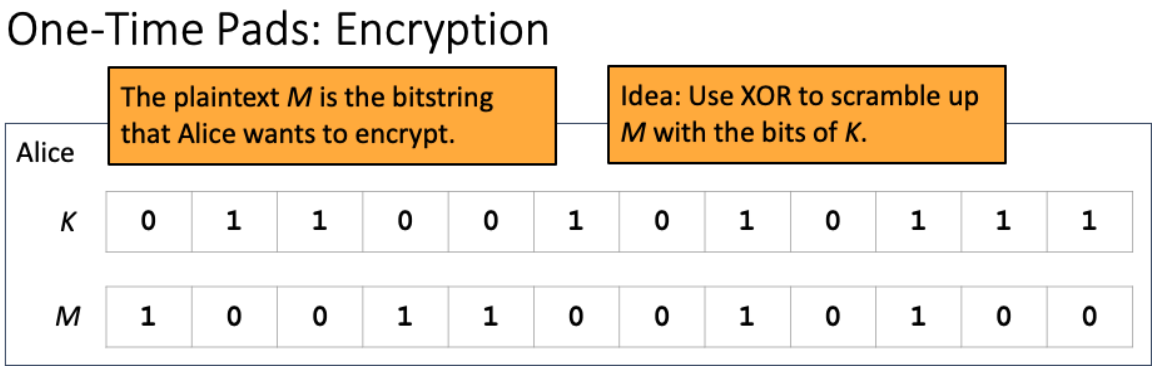
Useful properties of XOR:

$x \oplus 0 = x$
$x \oplus x = 0$
$x \oplus y = y \oplus x$
$(x \oplus y) \oplus z = x \oplus (y \oplus z)$
$(x \oplus y) \oplus x = y$

Question 4 Part A : Let's try out an example:

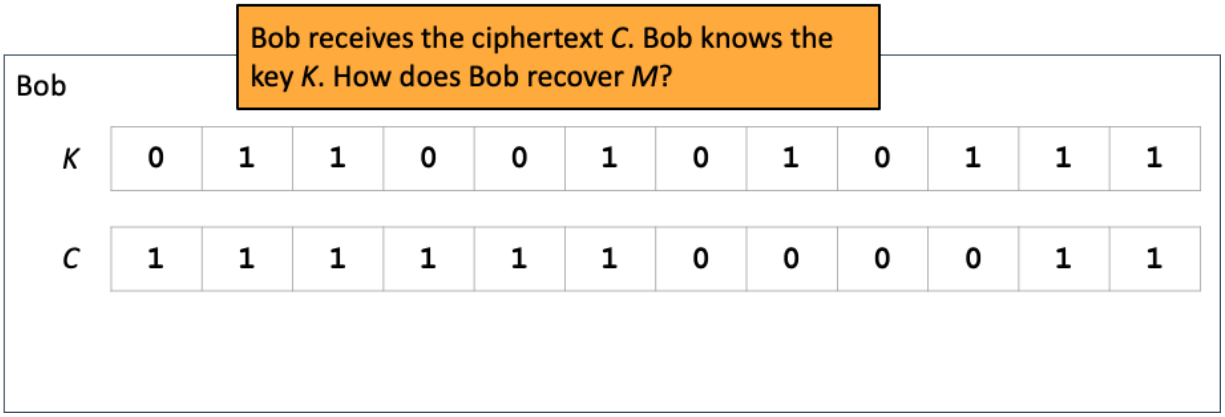
0100 1000 ^ 1010 0001 = ?

Question 4 Part B : The one time pad is a simple and idealized encryption scheme that helps illustrate some important concepts in security. What is the XOR of Alice's message with the key?



Question 4 Part C : Can Bob recover Alice's plaintext? Try using XOR of the Key and Ciphertext and see if you can retrieve the plaintext.

One-Time Pads: Decryption



Question 4 Part D : Is a one-time pad secure?

- What if the OTP Key is less than the length of the message? What if we reuse the OTP key?
- What are some issues that you can identify with OTPs?