# CRYPTOGRAPHY HANDOUT 03 SOLUTIONS

SUBSTITUTION CIPHER

## Substitution Example

The following example is from Douglas Stinson's Cryptography: Theory and Practice.

Given the ciphertext (encrypted with a substitution cipher):

```
YIFQFMZRWQFYVECFMDZPCVMRZWNMDZVEJBTXCDDUMJ
NDIFEFMDZCDMQZKCEYFCJMYRNCWJCSZREXCHZUNMXZ
NZUCDRJXYYSMRTMEYIFZWDYVZVYFZUMRZCRWNZDZJJ
XZWGCHSMRNMDHNCMFQCHZJMXJZWIEJYUCFWDJNZDIR
```

The following steps will walk through how to do the cryptanalysis.

1. Do a frequency count for the text.

| Letter | Count | Letter | Count |
|---|---|---|---|
| A | 0 | N | 9 |
| B | 1 | O | 0 |
| C | 15 | P | 1 |
| D | 13 | Q | 4 |
| E | 7 | R | 10 |
| F | 11 | S | 3 |
| G | 1 | T | 2 |
| H | 4 | U | 5 |
| I | 5 | V | 5 |
| J | 11 | W | 8 |
| K | 1 | X | 6 |
| L | 0 | Y | 10 |
| M | 16 | Z | 20 |

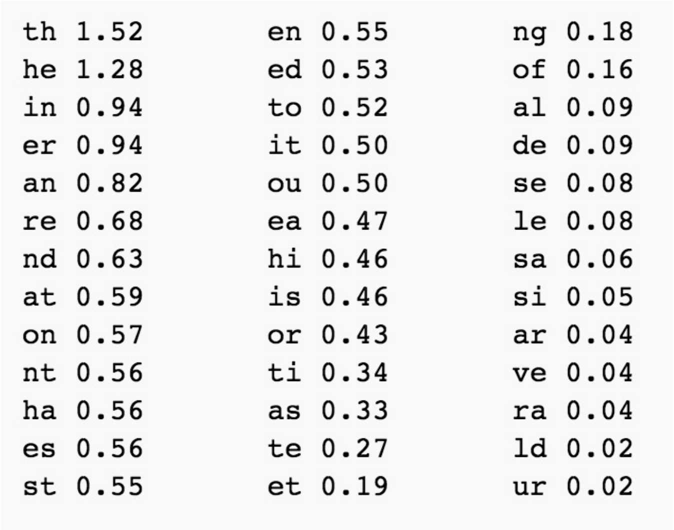
2. Which letter occurs most? This letter likely corresponds with e, the most frequency-occurring English letter.

   Z

3. The next set of most-frequent letters aren't as easy to match up. Let's look at the **bigrams** or digrams instead (pairs of letters). Count the following bigrams:

| Bigram | Count | Bigram | Count |
|---|---|---|---|
| DZ | 4 | ZW | 4 |
| NZ | 3 | ZU | 3 |

4. You should find that `DZ` and `ZW` occur the most often, so what are some guesses (based on the English language) that the letters corresponding to `D` and `W` are what? Use the bigram frequency table for reference:



| | | | | | |
|---|---|---|---|---|---|
| th | 1.52 | en | 0.55 | ng | 0.18 |
| he | 1.28 | ed | 0.53 | of | 0.16 |
| in | 0.94 | to | 0.52 | al | 0.09 |
| er | 0.94 | it | 0.50 | de | 0.09 |
| an | 0.82 | ou | 0.50 | se | 0.08 |
| re | 0.68 | ea | 0.47 | le | 0.08 |
| nd | 0.63 | hi | 0.46 | sa | 0.06 |
| at | 0.59 | is | 0.46 | si | 0.05 |
| on | 0.57 | or | 0.43 | ar | 0.04 |
| nt | 0.56 | ti | 0.34 | ve | 0.04 |
| ha | 0.56 | as | 0.33 | ra | 0.04 |
| es | 0.56 | te | 0.27 | ld | 0.02 |
| st | 0.55 | et | 0.19 | ur | 0.02 |

(From `https://en.wikipedia.org/wiki/Bigram#Bigram_frequency_in_the_English_language`.)

Since `Z` corresponds to `e`, then we guess that `D` corresponds to `h,r,t,d,s,v` and `W` corresponds to `r,s,n,d,a,t`.

5. We have a choice here. Suppose `W` corresponds to the plaintext letter of `d`. Since `ZRW` and `RZW` both occur at the beginning, and since `RW` occurs again later on and *nd* is a common digram, let's try saying that `R` corresponds to `n`. At this point, we have 3 letters deciphered. What does your text look like so far?

```
YIFQFMendQFYVECFMDZPCVMnedNMDeVEJBTXCDDUMJ

NDIFEFMDeCDMQeKCEYFCJMYrNCdJCSenEXCHeUNMXe

NeUCDnJXYYSMRTMEYIFedDYVeVYFeUMneCndNeDeJJ

XedGCHSMnNMDHNCMFQCHeJMXJedIEJYUCFdDJNeDIn
```

6. We can keep looking at bigrams and frequently-occurring letters to slowly fill in the rest of the letters until we get to the following message. Can you fill in the final letters?

```
o-r-riend-ro--arise-a-inedhise--t---ass-it

hs-r-riseasi-e-a-orationhadta-en--ace-hi-e

he-asnt-oo-in-i-o-redso-e-ore-ineandhesett

-ed-ac-inhischair-aceti-ted--to-ardsthes-n
```

The text should say:

Our friend from Paris examined his empty glass with surprise, as if evaporation had taken place while he wasn't looking. I poured some more wine and he settled back in his chair, face tilted up towards the sun. (*From P. Mayle's A Year in Provence.*)