COSC 2P03 — Assignment 2 — Transalphabetic encryption for fun and profit!

In computing, we tend to create binary representations for things that start with the premise of "all things being equal…", but how often are all things *not* equal?
(Often. The answer is often).
To some extent, we do see this acknowledged with some standard character encoding schemes like the ubiquitous UTF-8: it's a *variable-length* encoding scheme, that uses different numbers of bits for different characters, depending largely on… how English they are. Does that actually make sense? Across the planet, do we think the letter *q* (approximately one in every *thousand* English characters) really appears so much more often than 爱 that it warrants actually using fewer bytes to represent? (Yes, I realize the actual reason was to improve compatibility with ASCII, but… moving on)
Usually, whether we're using fixed-sized representations (like ASCII), or even variable-length representations (like UTF-8), we still use the same length within the same character set (i.e. all the glyphs within the same alphabet have the same number of allocated bits). *Should* that be the case?
For example, morse code uses varying numbers of dots and dashes for different characters, depending roughly on how frequently they appear in text. e.g. *E* and *T* are *dot* and *dash*, respectively. *J* and *Q* are far less common and each require *four* symbols.
Interesting how that works. In fact, if instead of dots and dashes, one were to consider 1s and 0s, one could devise a translation between traditional ASCII characters and some arbitrary alternate encoding scheme.

- But what if it *wasn't* standardized? How easy or difficult would it be to translate back?
  - Could this even be considered… an *encryption scheme*?

Well… *probably* not. At least not a cryptographically secure one. But certainly an interesting one to use as a thought experiment!

In such a scheme, you'd need three components:

- A transalphabetic *codex*, to map the original text into alternate binary patterns
- A *codebook* to map those patterns *back* to the original text
- An actual transformation of the original text, conforming to that standard

To be clear: we won't actually be working with raw binary; just the *text* of 0s and 1s. Again, it's an experiment.

Basic Requirements:
For this assignment you need to write two programs:

- A **command-line** tool that reads in text, creates a transalphabetic codex/codebook, and creates an 'encrypted' text file (consisting of the codebook, followed by binary patterns)
- A **command-line** tool that accepts an encrypted text file, and extracts the codebook to restore the original text (saving it into another file)

And you need to create a document:

- Draw a diagram showing a transalphabetic codex (tree), followed by its codebook (matchings), per below

Codebooks:
We'll start with the decryption first, because it's easier.
Suppose we had the following codebook:

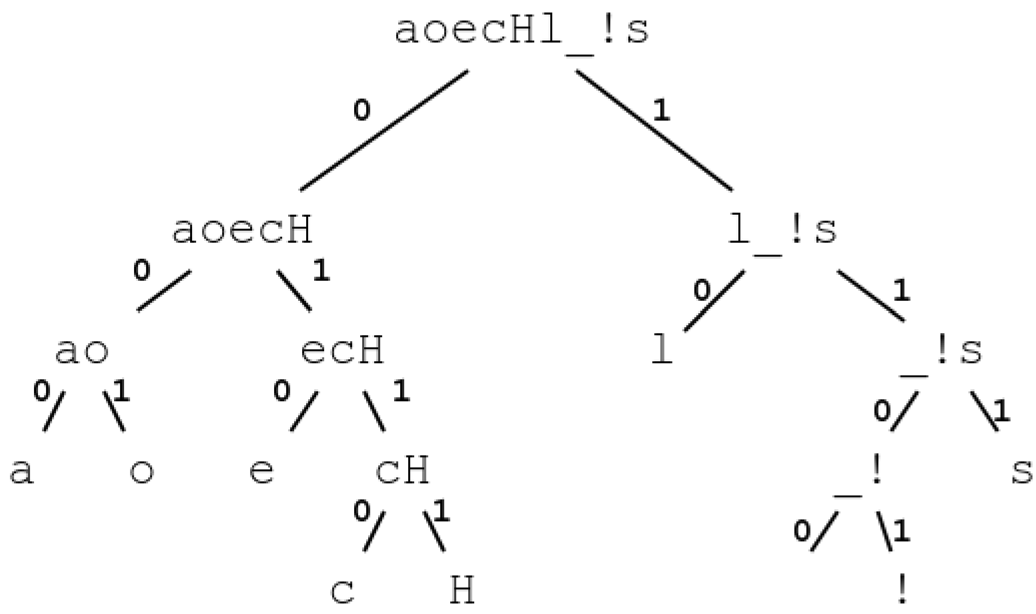
```
    1100
!   1101
H   0111
a   000
c   0110
e   010
l   10
o   001
s   111
```

...and the accompanying encrypted message:
`0111 010  10   10   001  1100 0110 10   000  111  111  1101`

Then the final recovered message would be:
`Hello class!`

As you can see, the 'codebook' is just the matching between one type of symbol and another. (In this case, a character/string, to a binary pattern) If it wasn't obvious, that first entry is for a *space*.
Notice how the letter 'l' is the *most common* to appear, and also has the *shortest* binary pattern. In a longer sequence of text (with more opportunities for repetition), it would also be very apparent that the *least-frequent* symbols received the *longest* patterns.
…so how'd we do that?

The transalphabetic codex:
The codex itself isn't *terribly* complicated. It's basically just a tree that you traverse to see which sequence of alternate symbols to build up. e.g. (substituting _ for the space):



And so, to find the symbolic pattern for any letter, just follow it down the tree (0s for 'left paths', and 1s for 'right paths'). In this case, a `c` would mean `0110`, and `!` would mean `1101`. The letter `l`, on the other hand, is `10`.

Generating the transalphabetic codex:
Again, the shortest patterns are allocated to the most common glyphs.

You start by generating a *frequency table*:

Letter	_	!	H	a	c	e	l	o	s
Freq.	1	1	1	1	1	1	3	1	2

Since `l` appears the most frequently, it needs the shortest path. Then `s`, and then whatever.

So what do we do? We actually *make* that tree! Specifically, we start with a *forest* of single-node-trees. Each node will have an attached *label* and *frequency*. (For a leaf node, the label's just the letter; for an internal node, it's the labels of all nodes within its subtrees)
You'll be devising something *like* a binary tree for this, though you'll need some extra code.
So you start with the following trees:

```
_:1   !:1   H:1   a:1   c:1   e:1   o:1   s:2   l:3
```

Now, you pick the *two* trees with the *lowest frequencies*, merge them, and re-add them to the pool.
When the numbers are equal, it doesn't matter which you take, so I'll go with the space and exclamation mark:

```
H:1   a:1   c:1   e:1   o:1   s:2  _!:2  l:3
                                   /  \
                                _:1    !:1
```

Notice that the frequency of a node includes the *sums* of its subtrees. Let's go for `c` and `H`:

```
a:1   e:1   o:1  cH:2  s:2  _!:2  l:3
                 /  \       /  \
              c:1    H:1 _:1    !:1
```

So long as we always pick the two trees with the lowest frequencies, it doesn't matter how else we decide.
So next, we could pick `ae`, `ao`, or `eo`. Let's go with `ao`:

```
e:1  ao:2       cH:2  s:2  _!:2  l:3
     /  \       /  \       /  \
  a:1    o:1 c:1    H:1 _:1    !:1
```

Now, we must pick `e`, but we can pick anything other than `l` for the other. Let's go with `cH`:

```
   ao:2  s:2  _!:2    l:3  ecH:3
   /  \       /  \         /  \
a:1    o:1 _:1    !:1  e:1    cH:2
                              /  \
                           c:1    H:1
```

We're down to only five trees! Making progress! Let's pick `_!` and `s`:

```
   ao:2      ecH:3       l:3   _!s:4
   /  \      /  \              /  \
a:1    o:1 e:1   cH:2      _!:2    s:2
                 /  \      /  \
              c:1    H:1 _:1    !:1
```

We *need* to pick `ao` next; let's pick `ecH` to go with it:

```
l:3   _!s:4            aoecH:5
      /  \             /    \
   _!:2   s:2     ao:2       ecH:3
   /  \           /  \       /  \
_:1    !:1     a:1    o:1 e:1    cH:2
                                 /  \
                              c:1    H:1
```

We must pick `l` and `_!s`:

```
        aoecH:5                 l_!s:7
        /   \                    /  \
    ao:2      ecH:3          l:3    _!s:4
   /  \       /  \                  /  \
a:1    o:1 e:1    cH:2          _!:2    s:2
                  /  \          /  \
               c:1    H:1    _:1    !:1
```

Of course, there are only two left, so we pick those:

```
                     aoecHl_!s:12
                    /            \
        aoecH:5                 l_!s:7
        /   \                    /  \
    ao:2      ecH:3          l:3    _!s:4
   /  \       /  \                  /  \
a:1    o:1 e:1    cH:2          _!:2    s:2
                  /  \          /  \
               c:1    H:1    _:1    !:1
```

And there we go! Since there's only one tree left, we're done!
By this point, you should have a reasonable guesstimate as to why we kept picking the tree with the *lowest* frequency: as we kept merging the trees, those infrequent letters ended up *way* down in the farthest leaves.

The only major question remaining is: how do we easily *accomplish* this?

- You'll probably make your own variation of a Node class to represent each of these label/frequency tokens. For the sake of comparison, they should probably be *Comparable*...
  - You'll need code *somewhere* that can follow these paths to leaves, to build up/return a binary pattern
- You'll need some sort of data structure that can readily *prioritize* one tree over another
  - Do we have any data structure that's good for that?

Encryption: `Encrypter.java`

So long as you're okay with each component of above, the rest should be pretty simple.

- Write a program that, based on some text input, creates a *frequency table* of possible characters
  - The input will come in an ASCII file, so you'll definitely never need to worry about more than 256 possible unique characters
  - The input text will *always* be *exactly* one line of text
    - It could be a monstrously-long line of text, including thousands of words, but you can still just use a single `nextLine` to read it
    - If you need individual characters, don't forget that String has a `.charAt()` and `.length()`; and `.toCharArray()`
- Use that frequency table to generate the initial forest of single-character-label trees
  - (Technically, you'll almost certainly still want the labels to be Strings, to simplify the code)
- Perform the algorithm above to create the transalphabetic codex (tree)
- Export the codebook to the *output file*
  - The output file will also just be plaintext

    - All you need to do is run through your frequency table, and put out a single line each of: character, a tab, and the binary pattern
        - You can get the binary pattern by walking through the tree (above)
        - Only output entries where the corresponding table entry had a frequency above zero
- The breakpoint between the codebook and the encrypted message is just three dashes: `---`
- Output the corresponding binary patterns of each character in the message, tab-separated

This is meant to be used command-line, so that means you need the option of *command-line arguments*!
Running it with no arguments assumes an input of `testing.txt` and an output of `encrypted.txt`.
With one argument, assume that's the input filename (with an output still of `encrypted.txt`).
With two arguments, they're the input and output filenames.

Decryption: `Decrypter.java`
This one's pretty straightforward, right? It's pretty much explained on Page 1. The only catches:

- The codebook and encrypted message are obviously separated by a line of `---`, per above
- The same command-line parameters apply as above, but with default names of `encrypted.txt`, and `recovered.txt`

Writeup:
To ensure you're comfortable with making *diagrams*, you need to include a reasonably-illustrated writeup.
(This document qualifies as adequately 'reasonable', so you don't need to go crazy with it)

Here's what you need to do:

- Submit both a marker-friendly `.pdf`, *and* the files you used to create it (`.docx`, `.tex`, whatever)
- It must contain:
    - A few sentences describing your favourite television show (or movie, or imaginary theatre production starring only llamas). Include punctuation, and several words, but remember: only *one* line
    - A frequency table of those sentences
    - A set of diagrams like above of *building* a possible tree from *that* frequency table
        - (It's *far* easier than it seems. You're welcome to just use your program to get the codex first, reverse-engineer a tree from that, and then pretend to be building-up said tree)
    - Your name, student number, and username
- Your diagrams must be proper, by which I mean don't just draw it in MS Paint
    - Use: https://app.diagrams.net/ (or its equivalent *draw.io* free downloadable program)
        - You *must* **export** from that tool; not use your phone, screenshot, etc.

General:
To clarify a few elements of the above:

- Put the `Encrypter` and `Decrypter` into an `enc` package
- Stick whatever you're using as general storage into a suitably-named package (*not* `enc`)
    - Remember: you're allowed to use code *I* gave you without citation
- Make sure you create your IntelliJ project properly. It should include both packages
    - You're going to need two Run Configurations:
        - One for the encrypter, and one for the decrypter
        - I can help you with this!

You'll need to use something like Scanner:
https://docs.oracle.com/javase/8/docs/api/java/util/Scanner.html

It's pretty easy to use to read from a file.
First, open the file (next page!):

```
Scanner input=null;
try {
	input=new Scanner(new File(infilename));
}
catch (IOException ioe) {System.out.println("Dernit!");} //don't use Dernit
```

After that, reading is trivial (I linked the API page for a reason).

We haven't done file output, but you can use this if you like:

```
private PrintWriter openFileForSave(String filename) {
	try {
		return new PrintWriter(new BufferedWriter(new FileWriter(filename)));
	}
	catch (IOException ioe) {System.out.println("Ah dangit.");}
	return null;
}
```

You don't *have* to, but it's stupid-easy, because all you'll need are `.print` and `.println`.

- In case you forgot: a *tab* is just `\t`

Remember: command-line arguments are a thing (that's what that `String[] args` stuff is!).
And again: configure your IntelliJ project correctly!

Submission:
Create `.pdf` output of sample executions of your program. **Zip** those, along with all source, development, and project files used to write the solution, the writeup, etc., and submit through Sakai.

Reminder: This is technically six pages long, so there's a lot to read. If you just skim through and ignore actual requirements, you'll get a zero. The marker won't put more work into grading than you put into your assignment.
Include *all* of the necessary files, make your program run as mandated, and don't write anything absurdly complicated or ridiculously obtuse.