Test 2: CPS 100

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Name: _____ (1 pt)

Login: _____

Honor code acknowledgment (signature) _____

	value	grade
Problem 1	10 pts.	
Problem 2	12 pts.	
Problem 3	8 pts.	
Problem 4	10 pts.	
Problem 5	29 pts.	
Problem 6	10 pts.	
TOTAL:	80 pts.	

This test has 10 pages, be sure your test has them all. Do NOT spend too much time on one question — remember that this class lasts 75 minutes.

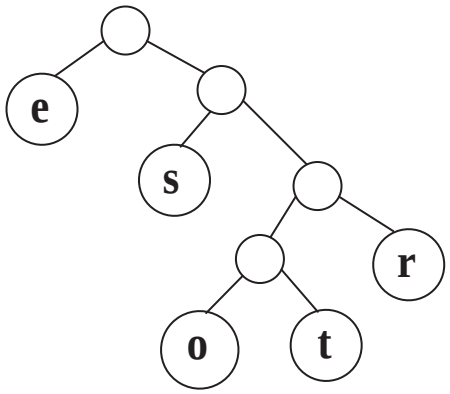
In writing code you do not need to worry about specifying the proper `#include` header files. Assume that all the header files we've discussed are included in any code you write.

Some common recurrences and their solutions.

`T(n) = T(n/2) + O(1)`	$O(\log n)$
`T(n) = T(n/2) + O(n)`	$O(n)$
`T(n) = 2T(n/2) + O(1)`	$O(n)$
`T(n) = 2T(n/2) + O(n)`	$O(n \log n)$
`T(n) = T(n-1) + O(1)`	$O(n)$
`T(n) = T(n-1) + O(n)`	$O(n^2)$

PROBLEM 1 : (***I'll huff and I'll puff and I'll ... (10 pts)***)

The Huffman tree below is used for this problem.



Part A (4 points)

Using this tree, decode the following Huffman-encoded bitstream

11111001100101101011 1

Part B (3 points)

Briefly, what was the reason for using the `PSEUDO_EOF` character in the Huffman coding program?

Part C (3 points)

The `tpqueue` class uses a heap for implementing a priority queue. In a heap, insert is $O(\log n)$ and deletemin is $O(\log n)$. Suppose you replace this heap-implementation in your Huffman compression program with an implementation that uses an unsorted vector — where the complexity of insert is $O(1)$ and the complexity of deletemin is $O(n)$. You will **not** notice any substantial change in the time it takes your program to run on nearly all files. Why?

PROBLEM 2 : (*AVL (12 points)*)

Part A: 4 points

The strings below are inserted, in the order shown, into an initially empty AVL tree. Draw the resulting tree. Note: there should be no rotations necessary when inserting these strings.

`"Monkey"`, `"Giraffe"`, `"Tiger"` `"Cheetah"`, `"Kangaroo"`,

Part B: 4 points

Using the tree you drew in Part A, insert the string `"Donkey"` into the tree so that the tree remains an AVL tree. Draw the resulting tree.

Part C: 4 points

Using the tree you drew in Part A, insert the string `"Lion"` into the tree so that the tree remains an AVL tree. Draw the resulting tree.

PROBLEM 3 : (***Like finding a needle in a Haystack (8 points)***)

The code below finds the smallest value in a stack, but empties the stack in finding the minimal value.

```
int min(tstack<int>& s)
// pre: s.size() >= 1
// post: returns smallest element in stack
//       stack is empty after function executes
{
    int min = s.top();
    s.pop();
    while (s.size() > 0) {
        int value;
        s.pop(value);
        if (value < min) {
            min = value;
        }
    }
    return min;
}
```

Write a version of `min` so that the stack passed in contains the same elements in the same order after the function executes. You may only define int variables in writing `min`, you may not define stacks, queues, vectors, etc. You'll need to make the function recursive to solve this problem. Note: the stack will be changed during the execution of `min`, but it should be restored to its original contents before `min` finishes.

```
int min(tstack<int>& s)
// pre: s.size() >= 1, stack = (s1, s2, ..., sn)
// post: returns smallest element in stack, stack = (s1, s2, ..., sn)
{









}
```

PROBLEM 4 : (*Heap o' Trouble (10 points)*)

Assume min-heaps are implemented using a vector as we discussed in class so that the root of the heap has index 1 and the children of the value stored at index k have indexes $2 \times k$ (left-child) and $2 \times k + 1$ (right-child).

Here is part of the class declaration for a heap that stores strings.

```
class StringHeap
{
    // public declarations not shown
    private:

      tvector<string> myList;
      int             mySize;  // number of elements in heap
};
```

The public member functions `StringHeap::getMin()` and `StringHeap::getMax()` follow (note: `getMax` is not a standard priority queue/heap function.)

```
string StringHeap::getMin() const {
// post: returns minimal element in heap
    return myList[1];
}

string StringHeap::getMax() const {
// post: returns maximal element in heap
    int maxIndex = 1;
    for(int k=maxIndex+1; k <= mySize; k++) {
        if (myList[k] > myList[maxIndex]) maxIndex = k;
    }
    return myList[maxIndex];
}
```

Part A (3 points)

In a heap with n elements, what is the big-Oh complexity of `StringHeap::getMin()` and why?

Part B (3 points)

In a heap with n elements, what is the big-Oh complexity of `StringHeap::getMax()` and why?

Part C (4 points)

Describe a *simple* change to the implementation of `StringHeap::getMax()` that will make the function roughly twice as fast although the big-Oh complexity will remain the same.

PROBLEM 5 : (*Multiset (29 points)*)

A multiset is similar to a set but stores duplicates. The code below on the left generates the output shown on the right and illustrates some of the multiset functions. `MultiSet::unique` returns the number of different elements in a MultiSet (ignoring duplicates). `MultiSet::size` returns the total number of elements in a MultiSet (including duplicates). `MultiSet::count` returns the number of occurrences of a specifiec string.

code

```
MultiSet multi;
multi.insert("apple");
multi.insert("cherry");
multi.insert("apple");
multi.insert("cherry");
multi.insert("apple");

cout << multi.count("apple") << endl;
cout << multi.count("cherry") << endl;
cout << multi.count("orange") << endl;
cout << "total = " << multi.size() << endl;
cout << "unique = " << multi.unique() << endl;
```

output

3
2
0
total = 5
unique = 2

Suppose member functions `MultiSet::insert` and `MultiSet::size` are implemented as follows where `myList` is a vector of strings.

```
void MultiSet::insert(const string& s) {
    myList.push_back(s);
}
int MultiSet::size() const {
    return myList.size();
}
```

Part A (4 pts)

Given these implementations, what is the big-Oh complexity of the function `MultiSet::count()`. Justify your answer.

Part B (4 pts)

Given these implementations, *describe* a method for implementing `MultiSet::unique` that runs in $O(n \log n)$ time. Justify why your solution is $O(n \log n)$. None of the other methods should change, but `MultiSet::unique` should run in $O(n \log n)$ time.

The code below is a partial implementation of a MultiSet class implemented using an `HMap` object. This implementation is used for the rest of this question (this code is duplicated on the separate code handout). This is a different implementation than used in parts A and B.

```
class MultiSet
{
  public:
    MultiSet();
    void insert(const string& s);           // add element to MultiSet
    int  count(const string& s) const;      // returns # occurrences of s
    int  size()                 const;      // returns total # elements
    int  unique()               const;      // returns # unique elements

  private:
    tmap<string,int> * myMap;
};

MultiSet::MultiSet()
    : myMap(new HMap<int>(10001))
// post: this MultiSet is empty
{

}

int MultiSet::unique() const
// post: returns # unique elements (repeats not counted) in this MultiSet
{
    return myMap->size();
}

void MultiSet::insert(const string& s)
// post: s is added to this MultiSet
{
    if (myMap->contains(s))  myMap->get(s)++;
    else                     myMap->insert(s,1);
}
```

Part C (4 pts)

Given this implementation write `MultiSet::count` so that it runs in $O(1)$ time in the average case.

```
int MultiSet::count(const string& s) const
// post: returns # times s occurs in this MultiSet
//       (returns 0 if s not in this MultiSet)
{









}
```

Part D (6 pts)

The member function `MultiSet::size` is implemented as follows:

```
int MultiSet::size() const
// post: returns total # elements (including repeated) in MultiSet
{
    int count = 0;
    Iterator<pair<string,int> > * it = myMap->makeIterator();
    for(it->Init(); it->HasMore(); it->Next()) {
        count += it->Current().second;
    }
    return count;
}
```

Describe modifications to the given `MultiSet` implementation that permit `MultiSet::size` to execute in $O(1)$ time. You must describe and write code for every change needed so that `MultiSet::size` runs in $O(1)$ time. None of the other methods should have their running time change. You can write the code on the previous page, or describe the changes in detail below (hint: add something to the private section that will engender changes in the class).

Part E (3 points)

If the `MultiSet` constructor creates a `BSTMap` instead of an `HMap`, will the implementations of the `MultiSet` member functions change? Why?

Part F (8 pts)

The code below creates a map for processing web-logs: files that store information about who visits web pages. The input file is in the format shown where the first string on a line is an Internet Protocal (IP) address and the second string is a URL for a web page visited by the corresponding IP address.

```
32.101.160.49   http://www.cs.duke.edu/~ola
32.101.160.49   http://www.cs.duke.edu/~ola/ethan
172.157.127.206 http://www.cs.duke.edu/education/courses/cps100/spring02
172.157.127.206 http://www.cs.duke.edu/education/courses/cps130/fall98
216.35.116.42   http://www.cs.duke.edu/~stefann
32.101.160.49   http://www.cs.duke.edu/~magda
32.101.160.49   http://www.cs.duke.edu/~ola
```

Here's the code for reading/storing log information from a file.

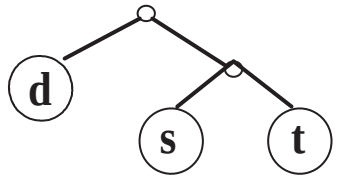
```
    tmap<string, MultiSet *> * map = new HMap<MultiSet *>(10001);
    ifstream input("logfile.txt");
    while (input >> ip >> url) {
        if (map->contains(ip)) map->get(ip)->insert(url);
        else {
            MultiSet * ss = new MultiSet();
            ss->insert(url);
            map->insert(ip,ss);
        }
    }
```

Write the function `maxUniqueVisits` that prints the IP address that visits the most *different* web pages. If there is more than one such IP address your code can print any one of them. In the sample web log above the IP `32.101.160.49` visits 3 different web pages which is moe than the number of pages visited by other IP addresses, so `32.101.160.49` should be printed.

```
void maxUniqueVisits(tmap<string, Multiset *> * map)
// pre: map stores information about IP -> web-page visits
// post: IP address that visits the most different web pages printed
{









}
```

PROBLEM 6 : (***Encore une fois (10 points)***)

A map of strings to ints associates an 8-bit/chunk (the value) with its Huffman encoding (the key). For example, `"10"` could be mapped to 's', and `"11"` mapped to 't' as shown in three below.



Complete the body of the function `map2tree` below that returns a pointer to the root of the Huffman tree representing the encodings in the map parameter. You will most likely find it useful to write a helper function called by `map2tree`, there's a blank page at the end of this test. You don't have to use the call of the helper function shown, but it's a good start. However, you're welcome to change completely the body of `map2tree`.

For example, given the mappings below, the tree above should be returned.

```
"0"   'd'
"10"  's'
"11"  't'

  struct TreeNode
  {
      int info;
      TreeNode * left;
      TreeNode * right;
      TreeNode(int value, TreeNode * lptr, TreeNode * rptr)
          : info(value), left(lptr), right(rptr)
        { }
  };

void mapTreeHelper(TreeNode * t, const string& path, int value);
// helper function prototype

TreeNode * map2tree(tmap<string,int> * map)
// pre:  map represents string->int encodings for a Huffman tree
//       map contains at least 2 (string,int) pairs
// post: returns pointer to root of Huffman tree representing the encodings
{


    Iterator<pair<string,int> > * it = map->makeIterator();

    for(it->Init(); it->HasMore(); it->Next()) {

          mapTreeHelper(        ,
                                                                  ,
                                                                    );
    }


}
```

blank page