CSCI-1200 Data Structures
Test 2 — Practice Problems

Note: This packet contains practice problems from three previous exams. Your exam will contain approximately one third as many problems.

1 Dynamic Tetris Arrays [/26]

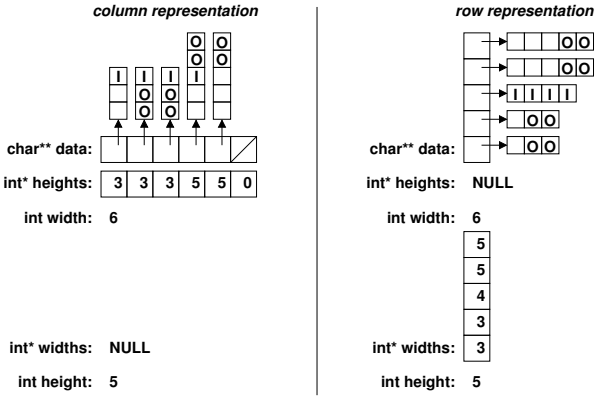
1.1 HW3 `Tetris` Implementation Order Notation [/6]

Match up the `Tetris` class member functions from HW3 with the appropriate order notation, where w is the width of the board and h is the maximum height of any column. Assume the solution is efficient, but uses only the 3 member variables specified in the original assignment (`data`, `heights`, and `width`).
Note: Some letters may be used more than once or not at all.

	`void add_piece(char piece,int rotation,int position);`	a) $O(1)$
	`int get_width();`	b) $O(w)$
	`int remove_full_rows();`	c) $O(h)$
	`int get_max_height();`	d) $O(w+h)$
	`void destroy();`	e) $O(w*h)$

1.2 `Tetris` Representation Conversion [/20]

Now let's revisit the details of the dynamic memory representation for the game of Tetris. Your task is to convert a Tetris board from the *column representation* we used for HW3 to a *row representation*. In addition to the three member variables in our HW3 Tetris class: `data`, `heights`, and `width`, we add 2 additional member variables: `widths` and `height`. In the column representation we don't need the `widths` variable, so it is set to `NULL`. Each time the board is modified to add Tetris pieces or score full rows the `height` variable is updated as necessary to store the maximum height of any column.



The diagram on the left shows an example `Tetris` board first in *column representation* and then in *row representation* — the "before" and "after" diagrams for a call to the new `Tetris` class member function `convert_to_row_representation`. Note that once in row representation the `heights` variable isn't needed and we set it to `NULL`. The `convert_to_row_representation` function takes no arguments.

Now write the `Tetris` class member function `convert_to_row_representation` as it would appear in the `tetris.cpp` implementation file. You may assume that before the call the board is in the column representation and the member variables are all set correctly. Make sure your code properly allocates new memory as needed and does not have memory leaks.

sample solution: 23 line(s) of code

2 Mystery Recursion [/9]

For each function or pair of functions below, choose the letter that best describes the program purpose or behavior.

A) infinite loop
B) factorial
C) integer power
D) the answer is 42
E) function is not recursive
F) sum of the digits
G) syntax error
H) modulo 2
I) reverse the digits
J) multiplication
K) greatest common divisor
L) other

```
int mysteryONE(int x, int y) {
  if(y == 0)
    return x;
  else
    return mysteryONE(y, x % y);
}
```

```
int mysteryFOUR(int x, int y) {
  if (x == 0)
    return 0;
  else
    return y +
      mysteryFOUR(x-1,y);
}
```

```
int mysteryTWO(int x) {
  if (x == 0)
    return 0;
  else
    return mysteryTWO(x/10)
           + x%10;
}
```

```
int mysteryFIVEa(int x, int y) {
  if (x == 0)
    return y;
  else
    return mysteryFIVEa
       (x/10, y*10 + x%10);
}

int mysteryFIVEb(int x) {
  return mysteryFIVEa(x,0);
}
```

```
int mysteryTHREEa(int x);

int mysteryTHREEb(int x) {
  if (x == 0)
    return 1;
  else
    return mysteryTHREEa(x-1);
}

int mysteryTHREEa(int x) {
  if (x == 0)
    return 0;
  else
    return mysteryTHREEb(x-1);
}
```

```
int mysterySIX(int x) {
  if (x == 0)
    return 1;
  else
    return x *
        mysterySIX(x-1);
}
```

3 Collecting Words [/ 18]

Write a function named `Collect` that takes in two *alphabetically sorted* STL `list`s of STL `string`s named `threes` and `candidates`. The function searches through the second list and removes all three letter words and places them in the first list in alphabetical order. For example, given these lists as input:

```
threes:      cup dog fox map
candidates:  ant banana egg goat horse ice jar key lion net
```

After the call to `Collect(threes, candidates)` the lists will contain:

```
threes:      ant cup dog egg fox ice jar key map net
candidates:  banana goat horse lion
```

If there are n and m words in the input lists, the order notation of your solution should be $O(n + m)$.

sample solution: 15 line(s) of code

4 Constantly Referencing `DSStudent` [/ 12]

The expected output of the program below is:

```
chris is a sophomore, his/her favorite color is blue, and he/she has used 1 late day(s).
```

However, there are a number of small but problematic errors in the `DSStudent` class code. Hint: This problem's title is relevant! Only one completely new line may be added (line 6), and the 7 other lines require one or more small changes. These lines are tagged with an asterisk, *. Your task is to rewrite each incorrect or missing line in the appropriately numbered box. *Please write the entire new line in the box.*

```
 1 class DSStudent {
 2  public:
* 3   DSStudent(std::string n, int y)
 4     : name(n) {
* 5     int entryYear = y;
* 6
 7   }
* 8   std::string& getName() const {
 9     return name;
10   }
*11   const std::string& getYear() {
12     if (entryYear == 2014) {
13       return "freshman"; }
14     } else if (entryYear == 2013) {
15       return "sophomore";
16     } else if (entryYear == 2012) {
17       return "junior";
18     } else {
19       return "senior";
20     }
21   }
*22   void incrLateDaysUsed() const {
23     days++;
24   }
*25   int& getLateDaysUsed() const {
26     return days;
27   }
*28   std::string FavoriteColor() {
29     return color;
30   }
31  private:
32   std::string name;
33   std::string color;
34   int entryYear;
35   int days;
36 };
37
38 int main() {
39   DSStudent s("chris",2013);
40   s.FavoriteColor() = "blue";
41   s.incrLateDaysUsed();
42   std::cout << s.getName()
43             << " is a " << s.getYear()
44             << ", his/her favorite color is " << s.FavoriteColor()
45             << ", and he/she has used " << s.getLateDaysUsed()
46             << " late day(s)." << std::endl;
47 }
```

3
5
6
8
11
22
25
28

5 Efficient Occurrences [/ 22]

Write a *recursive* function named `Occurrences` that takes in a *sorted* STL `vector` of STL `string`s named `data`, and an STL `string` named `element`. The function returns an integer, the number of times that `element` appears in `data`. Your function should have order notation $O(log\ n)$, where n is the size of `data`.

sample solution: 21 line(s) of code

6 Short Answer [/ 8]

6.1 What's Wrong? [/ 4]

Write 1-2 complete and concise sentences describing the problem with this code fragment:

```
std::vector<std::string> people;
people.push_back("sally");
people.push_back("brian");
people.push_back("monica");
people.push_back("fred");
std::vector<std::string>::iterator mom = people.begin() + 2;
std::vector<std::string>::iterator dad = people.begin() + 1;
people.push_back("paula");
std::cout << "My parents are " << *mom << " and " << *dad << std::endl;
```

6.2 Fear of Recursion [/ 4]

Rewrite this function without recursion:

```
class Node {
public:
  std::string value;
  Node* next;
};
```

```
void printer (Node* n) {
  if (n->next == NULL) {
    std::cout << n->value;
  } else {
    std::cout << "(" << n->value << "+";
    printer (n->next);
    std::cout << ")";
  }
}
```

sample solution: 13 line(s) of code

7 Converting Between `Vec` and `dslist` [/ 26]

Ben Bitdiddle is working on a project that stores data with two different data structures: our `Vec` and `dslist` classes. Occasionally he needs to convert data from one format to the other format. Alyssa P. Hacker suggests that he write a copy-constructor-like function for each class that takes in a single argument, the original format of the data. For example, here's how to convert data in `Vec` format to `dslist` format:

```
// create a Vec object with 4 numbers
Vec<int> v;  v.push_back(1);  v.push_back(2);  v.push_back(3);  v.push_back(4);
// create a dslist object that initially stores the same data as the Vec object
dslist<int> my_lst(v);
```

Here are the relevant portions of the two class declarations (and the `Node` helper class):

```
template <class T> class Vec {
public:
  // conversion constructor
  Vec(const dslist<T>& lst);
  /* other functions omitted */
  // representation
  T* m_data;
  unsigned int m_size;
  unsigned int m_alloc;
};
```

```
template <class T> class Node {
public:
  Node(const T& v):
    value_(v),next_(NULL),prev_(NULL){}
  T value_;
  Node<T>* next_;
  Node<T>* prev_;
};

template <class T> class dslist {
public:
  // conversion constructor
  dslist(const Vec<T>& vec);
  /* other functions omitted */
  // representation
  Node<T>* head_;
  Node<T>* tail_;
  unsigned int size_;
};
```

Ben asks about access to the private member variables of one class from a member function of the other. Alyssa says he can write the functions assuming he has full access to the private member variables. (She promises to teach him how to use the `friend` keyword to make that work after Test 2.)

7.1 Diagrams [/ 8]

First, draw the detailed internal memory representations for a `Vec` object and a `dslist` object, each storing the numbers: `1 2 3 4`.

m_data:
m_alloc:
m_size:

tail_:
head_:
size_:

7.2 Implementing the Conversion Constructors [/ 18]

Now write the two conversion constructors. You may not use `push_back`, `push_front`, `insert` or iterators in your answer. Instead, demonstrate that you know how to construct and manipulate the low level memory representation.

```
template <class T> Vec<T>::Vec(const dslist<T>& lst) {
```

sample solution: 13 line(s) of code

```
template <class T> dslist<T>::dslist(const Vec<T>& v) {
```

sample solution: 13 line(s) of code

8 Matrix Transpose [/ 20]

First, study the partial implementation of the templated `Matrix` class on the right. Your task is to implement the `transpose` member function for this class (as it would appear outside of the class declaration). Remember from math class that the transpose flips the matrix data along the diagonal from the upper left corner to the lower right corner. For example:

$$\begin{bmatrix} a & b & c \\ d & e & f \end{bmatrix} \xrightarrow{transpose} \begin{bmatrix} a & d \\ b & e \\ c & f \end{bmatrix}$$

```
template <class T> class Matrix {
public:
  Matrix(int rows, int cols, const T &v);
  ~Matrix();
  int getRows() const { return rows_; }
  int getCols() const { return cols_; }
  const T& get(int r, int c) const
    { return values[r][c]; }
  void set(int r, int c, const T &v)
    { values[r][c] = v; }
  void transpose();
private:
  int rows_;
  int cols_;
  T **values;
};
```

sample solution: 18 line(s) of code

9 Book, Page, Sentence, & Word Iteration [/ 18]

Write a function `PageWithMostSentencesWithWord` that takes in two arguments. The first argument is an STL `list` of STL `list`s of STL `list`s of STL `string`s that represents a book with pages. Each page has multiple sentences. Each sentence has multiple words. The second argument is an STL `string` with the search word. The function should return the page number that has the most sentences that contain the search word. The first page in the book is numbered 1 (not zero). You may assume that any punctuation has already been removed and everything has been converted to lowercase.

sample solution: 24 line(s) of code

10 Linear 2048 [/ 18]

Write a *recursive* function named `Linear2048` that takes in an STL list of integers and plays a single line based version of the 2048 game. If two adjacent numbers are equal to each other in value, those two elements merge and are replaced with their sum. The function returns the maximum value created by any of the merges during play. The example shown on the right reduces the original input list with 17 values to a list with 4 values and returns the value 2048.

```
8 2 2 1024 256 32 16 8 4 1 1 2 32 32 128 512 32
8 4 1024 256 32 16 8 4 1 1 2 32 32 128 512 32
8 4 1024 256 32 16 8 4 2 2 32 32 128 512 32
8 4 1024 256 32 16 8 4 4 32 32 128 512 32
8 4 1024 256 32 16 8 8 32 32 128 512 32
8 4 1024 256 32 16 16 32 32 128 512 32
8 4 1024 256 32 32 32 32 128 512 32
8 4 1024 256 64 32 32 128 512 32
8 4 1024 256 64 64 128 512 32
8 4 1024 256 128 128 512 32
8 4 1024 256 256 512 32
8 4 1024 512 512 32
8 4 1024 1024 32
8 4 2048 32
```

sample solution: 15 line(s) of code

11 Mystery Function Memory Usage Order Notation [/ 6]

What does this function compute? What is the order notation of the size of the memory necessary to store the return value of this function? Give your answer in terms of n, the number of elements in the input vector, and k, the average or worst case length of each string in the input vector. Write 3-4 concise and well-written sentences to justify your answer.

```
std::vector<std::string> mystery(const std::vector<std::string> &input) {
  if (input.size() == 1) { return input; }
  std::vector<std::string> output;
  for (int i = 0; i < input.size(); i++) {
    std::vector<std::string> helper_input;
    for (int j = 0; j < input.size(); j++) {
      if (i == j) continue;
      helper_input.push_back(input[j]);
    }
    std::vector<std::string> helper_output = mystery(helper_input);
    for (int k = 0; k < helper_output.size(); k++) {
      output.push_back(input[i]+", "+helper_output[k]);
    }
  }
  return output;
}
```

12 LeapFrogSplit on a Doubly-Linked List [/ 26]

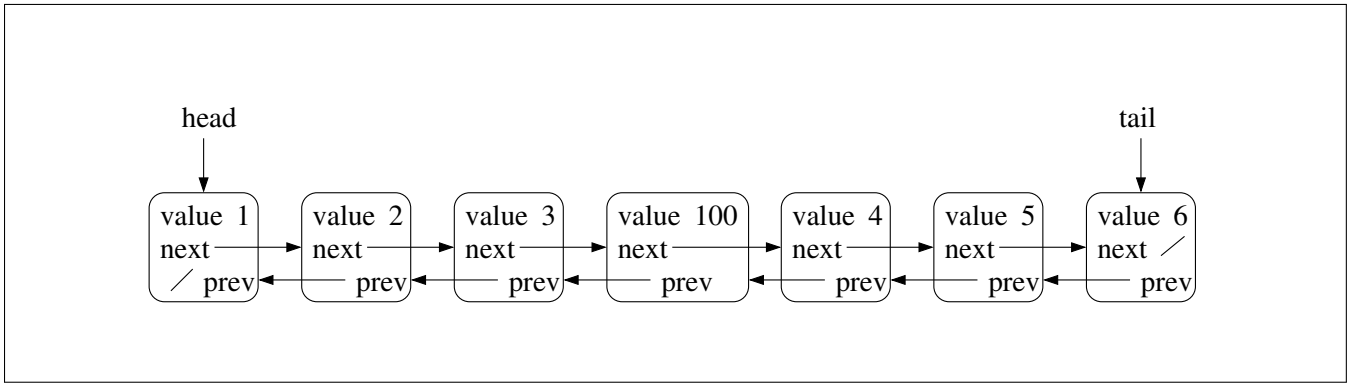
In this problem, we will implement the `LeapFrogSplit` function which manipulates a doubly-linked list of `Node`s. This function takes in 3 arguments: pointers to the *head* & *tail* `Node`s of a doubly-linked list, and an integer *value*. The function locates the `Node` containing that value, removes the node, splits the value in half, and re-inserts the half values into the list jumping over both of the original neighbors before and after it in the list.

For example, if the linked list initially contains 7 nodes with the data: `1 2 3 100 4 5 6`, then after executing `LeapFrogSplit(head,tail,100)` it will contain 8 nodes: `1 2 50 3 4 50 5 6`.

```
class Node {
public:
  Node(int v) :
    value(v),
    next(NULL),
    prev(NULL) {}
  int value;
  Node* next;
  Node* prev;
};
```

12.1 Diagram [/ 5]

First, modify the diagram below to illustrate the result of `LeapFrogSplit(head,tail,100)`.



12.2 Corner Cases & Testing [/ 7]

What "corner cases" do you need to consider for this implementation? Give 4 interesting examples of input and what you define as the correct result for each case. Write 2-3 explanatory sentences as needed.

12.3 Implementing `LeapFrogSplit` [/ 14]

Finally, write `LeapFrogSplit`. Focus primarily on correctly performing the general case that we diagrammed on the previous page. Corner cases are worth only a small number of points.

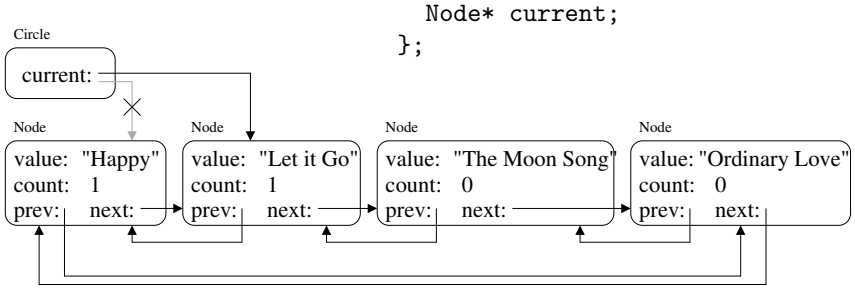
sample solution: 36 line(s) of code

13 Circular Play List [/ 27]

In this problem we will create a simple doubly-linked circular data structure to store a play list of songs represented as STL `string`s. Here's a portion of the class declaration:

```
class Node {
public:
  Node(const std::string& val) :
    value(val), count(0),
    prev(NULL), next(NULL) {}
  std::string value;
  int count;
  Node* prev;
  Node* next;
};
```

```
class Circle {
public:
  //
  // PROTOTYPES OF TWO FUNCTIONS YOU WILL WRITE
  //
  void play();
private:
  Node* current;
};
```



And here is a sample usage of the `Circle` class to store the Oscar nominees for "Best Song":

```
  std::vector<std::string> songs;
  songs.push_back("Happy");
  songs.push_back("Let it Go");
  songs.push_back("The Moon Song");
  songs.push_back("Ordinary Love");
  Circle oscar_nominees(songs);
  for (int i = 0; i < 3; i++) {
    oscar_nominees.play(); }
  std::cout << "--- editing the song list ---" << std::endl;
  bool success = oscar_nominees.remove("Let it Go");
  assert (success == true);
  success = oscar_nominees.remove("Atlas");
  assert (success == false);
  for (int i = 0; i < 6; i++) {
    oscar_nominees.play(); }
```

Which results in this output:

```
  now playing: Happy
  now playing: Let it Go
     (last song was Happy)
  now playing: The Moon Song
     (last song was Let it Go)
  --- editing the song list ---
  now playing: Ordinary Love
     (last song was The Moon Song)
  now playing: Happy, played 1 time(s) previously
     (last song was Ordinary Love)
  now playing: The Moon Song, played 1 time(s) previously
     (last song was Happy)
  now playing: Ordinary Love, played 1 time(s) previously
     (last song was The Moon Song)
  now playing: Happy, played 2 time(s) previously
     (last song was Ordinary Love)
  now playing: The Moon Song, played 2 time(s) previously
     (last song was Happy)
```

Here's the implementation of one of the functions used on the previous page. You need to implement the other two missing functions so that the program performs as shown in the example.

```
void Circle::play() {
  if (current == NULL) return;
  std::cout << "now playing: " << current->value;
  if (current->count > 0) {
    std::cout << ", played " << current->count << " time(s) previously";
  }
  std::cout << std::endl;
  if (current->prev->count != 0)
    std::cout << "   (last song was " << current->prev->value << ")" << std::endl;
  current->count++;
  current = current->next;
}
```

13.1 `Circle` constructor [/ 12]

First, implement the constructor used in the example on the previous page as it would appear in the `.cpp` file. Of course, make sure your function also handles input song lists with more or fewer songs.

sample solution: 15 line(s) of code

13.2 Implementing `remove` [/ 15]

Now, implement the `remove` function as it would appear in the `.cpp`. Study the provided example carefully, but also make sure that your function works for all corner cases as well.

sample solution: 21 line(s) of code

14 Common Data [/ 20]

Write a templated function `common_data` that takes in two STL `vector`s of type `T` and returns an STL `vector` of type T that contains all of the common elements; that is, only if an element is in *both* of the input vectors will it be added to the output vector. The input vectors may contain duplicates, but your output vector should not. You are not allowed to edit the input vectors.

sample solution: 22 line(s) of code

Order Notation If there are n elements in the first input vector and m elements in the second input vector, what is the order notation of your solution?

15 Possessive Grammar [/ 22]

Write a function `convert_to_possessive` that takes in one argument, an STL `list` of `string`s representing a sentence, and edits the sentence to replace the pattern "the AAA of BBB" with "BBB's AAA".

For example,	`i like the hat of sarah`
is rewritten as	`i like sarah's hat`
And	`the car of joe is parked between the van of chris and a motorcycle`
is rewritten as	`joe's car is parked between chris's van and a motorcycle`

You may assume that the words are all lowercase and the input sentence contains no punctuation.

sample solution: 21 line(s) of code

16 Mysterious Memory Errors [/ 15]

The program below contains numerous memory-related errors. Your task is to identify and fix each problem.

```
01  int main() {
02    int max_index = 20;
03    int* data = new int[max_index];
04    data[0] = 0;
05    data[1] = 1;
06    int* tmp = new int;
07    for (int i = 0; i < max_index; i++) {
08      *tmp = data[i] + data[i+1];
09      data[i+2] = *tmp;
10    }
11    int* answer = new int;
12    for (tmp = data; tmp < data+max_index; tmp++) {
13      if (*tmp % 2 == 1) (*answer)++;
14    }
15    tmp = answer;
16    std::cout << "mystery answer => " << *answer << std::endl;
17    delete data;
18    delete answer;
19    delete tmp;
20    return 0;
21  }
```

A MEMORY LEAK is reported for the allocation on line [ ]. It can be fixed by moving line [ ] immediately after line [ ]. (Note: the line is causing a MEMORY ALREADY FREED error in its current location.) The memory debugger reports use of UNINITIALIZED MEMORY on line [ ]. It can be fixed by adding this line of code [ ] immediately after line [ ]. A MISMATCHED NEW/NEW[]/DELETE/DELETE[] is reported on line [ ]. It is fixed by changing that same line to [ ].

An INVALID READ is reported on line [ ] and an INVALID WRITE is reported on line [ ]. Both errors can be fixed by editing line [ ] to be [ ].

Once all of these errors are corrected, the program calculates a simple, yet interesting, statistic. Describe in 1 or 2 sentences the mystery answer calculated by this program.

[ ]

17 Recursive Order Notation Challenge [/ 13]

Write a recursive function `FooA` that takes a single integer argument n that has order notation $O(n)$.

sample solution: 7 line(s) of code

Write a recursive function `FooB` that takes a single integer argument n that has order notation $O(\log\ n)$.

sample solution: 7 line(s) of code

Write a recursive function `FooC` that takes a single integer argument n that has order notation $O(2^n)$.

sample solution: 7 line(s) of code