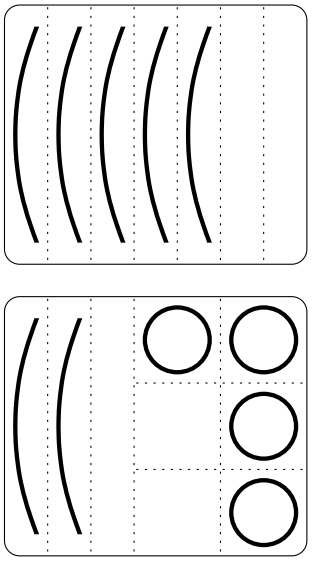
CSCI-1200 Data Structures
Test 1 — Practice Problem Solutions

1 Loading the Dishwasher [/33]



In this problem you will implement a simple class named `Dishwasher` to keep track of the contents of a dishwasher as it's being loaded with plates, cups, forks, knives, and spoons. The total volume of a `Dishwasher` is measured in number of plates. The diagram on the right shows a dishwasher that has room to hold 7 plates. If we want to wash a mix of plates and cups, we can load 3 cups in the space normally occupied by 2 plates. Note: There is no limit on space for forks, knives, or spoons. *We never run out of space for utensils!*

Here's how we create a new dishwasher object, specifying the volume in number of plates:

```
Dishwasher dw(7);
```

And here's how we begin to load the dishwasher. Note that we perform error checking each time we add a cup or plate. None of the error checks in this portion of the example are triggered.

```
if (!dw.addPlate("blue"))  { std::cerr << "ERROR  1: cannot add another plate" << std::endl; }
if (!dw.addPlate("red"))   { std::cerr << "ERROR  2: cannot add another plate" << std::endl; }
if (!dw.addPlate("green")) { std::cerr << "ERROR  3: cannot add another plate" << std::endl; }
if (!dw.addCup())          { std::cerr << "ERROR  4: cannot add another cup"   << std::endl; }
if (!dw.addPlate("green")) { std::cerr << "ERROR  5: cannot add another plate" << std::endl; }
if (!dw.addPlate("red"))   { std::cerr << "ERROR  6: cannot add another plate" << std::endl; }
if (!dw.addCup())          { std::cerr << "ERROR  7: cannot add another cup"   << std::endl; }
dw.addSpoon();  dw.addFork();  dw.addKnife();  dw.addFork();   dw.addSpoon();
dw.addFork();   dw.addFork();  dw.addKnife();  dw.addSpoon();  dw.addFork();
```

Next, we print the contents of the dishwasher and the number of complete sets of utensils (1 fork + 1 knife + 1 spoon). *It seems like we always have extra forks!*

```
dw.printContents();
std::cout << dw.completeUtensilSets() << " complete utensil set(s)" << std::endl;
```

Here is the output (to `std::cout`) after the above statements. Note that we print the colors of the plates in the order they were inserted.

```
5 plate(s): blue red green green red
2 cup(s)
10 utensil(s)
2 complete utensil set(s)
```

Finally, let's explore what happens if we try to load more cups & plates into the dishwasher...

```
if (!dw.addPlate("red"))   { std::cerr << "ERROR  8: cannot add another plate" << std::endl; }
if (!dw.addCup())          { std::cerr << "ERROR  9: cannot add another cup"   << std::endl; }
if (!dw.addCup())          { std::cerr << "ERROR 10: cannot add another cup"   << std::endl; }
```

Two of these additions fail, as we can see by this output to `std::cerr`:

```
ERROR  8: cannot add another plate
ERROR 10: cannot add another cup
```

1.1 `Dishwasher` Class Declaration [/15]

Using the sample code on the previous page as your guide, write the class declaration for the `Dishwasher` object. That is, write the *header file* (`dishwasher.h`) for this class. You don't need to worry about the `#include` lines or other pre-processor directives. Focus on getting the member variable types and member function prototypes correct. Use `const` and call by reference where appropriate. Make sure you label what parts of the class are `public` and `private`. Save the implementation of all functions > 1 line for the `dishwasher.cpp` file, which is the next part.

Solution:

```
class Dishwasher {
public:
  // CONSTRUCTOR
  Dishwasher(int max_plates);
  // PRINT & ACCESSORS
  void printContents() const;
  int completeUtensilSets() const;
  // MODIFIERS
  bool addPlate(const std::string& color);
  bool addCup();
  void addFork()  { forks++; }
  void addSpoon() { spoons++; }
  void addKnife() { knives++; }
private:
  // PRIVATE HELPER FUNCTION
  bool valid_counts(int p, int c) const;
  // REPRESENTATION
  int max_plates;
  std::vector<std::string> plates;
  int cups;
  int forks;
  int knives;
  int spoons;
};
```

1.2 `Dishwasher` Class Implementation [/18]

Now implement the member functions, as they would appear in the corresponding `dishwasher.cpp` file.

Solution:

```
// CONSTRUCTOR
Dishwasher::Dishwasher(int max_p) {
  cups = forks = knives = spoons = 0;
  max_plates = max_p;
}

// PRINT & ACCESSORS
void Dishwasher::printContents() const {
  std::cout << plates.size() << " plate(s):";
  for (int i = 0; i < plates.size(); i++) { std::cout << " " << plates[i]; }
  std::cout << std::endl;
  std::cout << cups << " cup(s)" << std::endl;
  std::cout << forks+knives+spoons << " utensil(s)" << std::endl;
}
int Dishwasher::completeUtensilSets() const {
  return std::min(std::min(forks,knives),spoons);
}

// MODIFIERS
bool Dishwasher::addPlate(const std::string& color) {
  if (valid_counts(plates.size()+1,cups)) {
    plates.push_back(color);
    return true;
  }
  return false;
}
bool Dishwasher::addCup() {
  if (valid_counts(plates.size(),cups+1)) {
    cups++;
    return true;
  }
  return false;
}
```

```
// PRIVATE HELPER FUNCTION
bool Dishwasher::valid_counts(int p, int c) const {
  return (p + ceil(c/3.0)*2 <= max_plates);
}
```

2 Resizable Histogram [/20]

Let's build a histogram of students organized by their grade on Homework 1 into buckets of size 5. An example of the data is to the right and the expected output is on the far right.

hw1_scores.txt	std::cout
alice 30	[0- 4]
bob 32	[5- 9]
chris 23	[10-14] fred
dan 29	[15-19]
erin 39	[20-24] chris
fred 10	[25-29] dan georgia
georgia 27	[30-34] alice bob harry
harry 30	[35-39] erin

First, write a fragment of code (as it would appear in `main.cpp`) to open the file `hw1_scores.txt` and read the data into an STL `vector` of STL `vector`s of STL `string`s. The vector should be resized as necessary to adapt to the maximum score present in the file.

Solution:

```
// open the file
std::ifstream istr("hw1_scores.txt");
assert (istr.good());
// variables to parse the file & store the data
std::string name;
int score;
std::vector<std::vector<std::string> > histogram;
// read the file
while (istr >> name >> score) {
  int bucket = score / 5;
  for (int i = histogram.size(); i <= bucket; ++i) {
    // add additional buckets if needed
    histogram.push_back(std::vector<std::string>());
  }
  // insert this student into the correct bucket
  histogram[bucket].push_back(name);
}
```

Next, write code to output the data stored in the vector to `std::cout` as shown above.

Solution:

```
// loop over all of the buckets
for (int i = 0; i < histogram.size(); i++) {
  // print the bucket range
  std::cout << "[" << std::setw(2) << i*5 << "-" << std::setw(2) << (i+1)*5-1 << "]";
  for (int j = 0; j < histogram[i].size(); ++j) {
    // print the names
    std::cout << " " << histogram[i][j];
  }
  std::cout << std::endl;
}
```

3 Sorting L33T5P34K (a.k.a. LEETSPEAK) [/15]

We saw in Homework 2 that the default sorting of STL `string` objects places numerical digits (`Ø`-`9`) before capital letters (`A`-`Z`). Therefore, following the STL defaults, this sequence of strings is considered sorted:

```
3ND 4ND 5LØP 5L1P 5L3PT 5L4P DØG D1G
```

Let's instead view these strings as English words encoded by 1980's hackers or texting teenagers in so-called *LEETSPEAK*, using these substitutions: `Ø`↔`O`, `1`↔`I`, `3`↔`E`, `4`↔`A`, and `5`↔`S`. Therefore, this is a more appropriate alphabetization of these strings:

```
4ND D1G DØG 3ND 5L4P 5L3PT 5L1P 5LØP
```

Implement a function named `leetspeak_sorter`, that may be passed to the STL `sort` routine for STL `vectors` to

alphabetize a collection of LEETSPEAK words. You may assume all characters of these words are either capital letters or numbers and use only the letter substitutions listed above.

Solution:

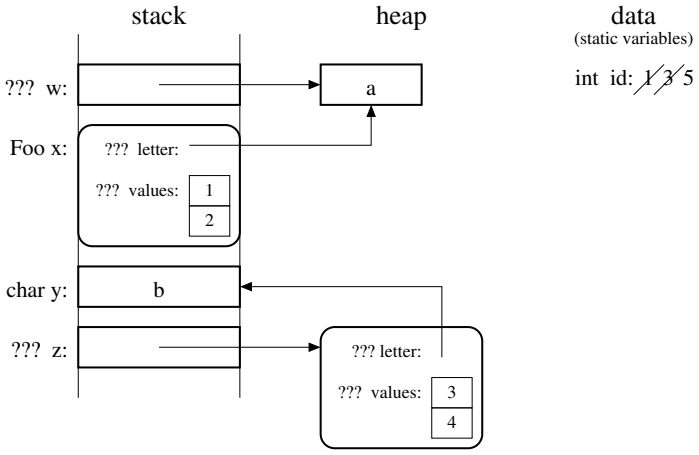
```
std::string leetspeak(const std::string &w) {
  std::string answer = w;
  for (int i = 0; i < w.size(); i++) {
    if (w[i] == '4') answer[i] = 'A';
    if (w[i] == '3') answer[i] = 'E';
    if (w[i] == '1') answer[i] = 'I';
    if (w[i] == '0') answer[i] = 'O';
    if (w[i] == '5') answer[i] = 'S';
  }
  return answer;
}

bool leetspeak_sorter(const std::string &a, const std::string &b) {
  return leetspeak(a) < leetspeak(b);
}
```

4 Memory Diagramming [/20]

Write code to produce the memory structure shown in the diagram to the right.

Some types have been omitted (marked with "???").



Solution:

```
class Foo {
public:
  Foo(char* l);
private:
  char* letter;
  int values[2];
};

Foo::Foo(char *l) {
  static int id = 1;
  letter = l;
  values[0] = id;
  values[1] = id+1;
  id += 2;
}

int main() {
  char* w = new char;
  *w = 'a';
  Foo x(w);
  char y = 'b';
  Foo* z = new Foo(&y);
}
```

5 Opening a New Hair Salon [/32]

In this problem you will implement a simple class named `Customer` to keep track of customers at a hair salon. First, we create 6 `Customer` objects:

```
Customer betty("Betty");     Customer chris("Chris");     Customer danielle("Danielle");
Customer erin("Erin");       Customer fran("Fran");       Customer grace("Grace");
```

Then, we can track customers as they come to the salon for appointments on specific dates with one of the salon's stylists. We use the `Date` class we discussed in Lecture 2. You may assume the appointments are entered chronologically, with increasing dates.

```
betty.hairCut   (Date(1,15,2015), "Stephanie");
chris.hairCut   (Date(1,17,2015), "Audrey"   );
grace.hairCut   (Date(1,20,2015), "Stephanie");
danielle.hairCut(Date(1,28,2015), "Stephanie");
chris.hairCut   (Date(2, 5,2015), "Audrey"   );
betty.hairCut   (Date(2, 9,2015), "Stephanie");
fran.hairCut    (Date(2,12,2015), "Audrey"   );
danielle.hairCut(Date(2,18,2015), "Lynsey"   );
betty.hairCut   (Date(2,20,2015), "Stephanie");
```

In the system, each customer record will store the customer's preferred stylist. The preferred stylist is defined as a customer's most recent stylist. A message is printed to `std::cout` on each customer's first visit to the salon, or if a customer switches to a new stylist. Here is the output from the above commands:

```
Setting Stephanie as Betty's    preferred stylist.
Setting Audrey    as Chris's    preferred stylist.
Setting Stephanie as Grace's    preferred stylist.
Setting Stephanie as Danielle's preferred stylist.
Setting Audrey    as Fran's     preferred stylist.
Setting Lynsey    as Danielle's preferred stylist.
```

Next, we insert the customers into an STL `vector`:

```
std::vector<Customer> customers;
customers.push_back(betty);  customers.push_back(chris);  customers.push_back(danielle);
customers.push_back(erin);   customers.push_back(fran);   customers.push_back(grace);
```

And then sort & print them first alphabetically by stylist, and secondarily by most recent visit to the salon:

```
std::sort(customers.begin(),customers.end(),stylist_then_last_appointment);
for (int i = 0; i < customers.size(); i++) {
   std::cout << customers[i].getName() << " has had "
             << customers[i].numAppointments() << " appointment(s) at the salon";
   if (customers[i].numAppointments() > 0) {
      std::cout << ", most recently with " << customers[i].getStylist()
                << " on " << customers[i].lastAppointment(); }
   std::cout << "." << std::endl;
}
```

Which results in this output to the screen:

```
Erin     has had 0 appointment(s) at the salon.
Chris    has had 2 appointment(s) at the salon, most recently with Audrey    on  2/ 5/2015.
Fran     has had 1 appointment(s) at the salon, most recently with Audrey    on  2/12/2015.
Danielle has had 2 appointment(s) at the salon, most recently with Lynsey    on  2/18/2015.
Grace    has had 1 appointment(s) at the salon, most recently with Stephanie on  1/20/2015.
Betty    has had 3 appointment(s) at the salon, most recently with Stephanie on  2/20/2015.
```

Note: Don't worry about output formatting/spacing. You may assume that the `Date` class has an `operator<` to compare/sort dates chronologically and an `operator<<` to print/output `Date` objects.

5.1 `Customer` Class Declaration [/15]

Using the sample code on the previous page as your guide, write the class declaration for the `Customer` object. That is, write the *header file* (`customer.h`) for this class. You don't need to worry about the `#include` lines or other pre-processor directives. Focus on getting the member variable types and member function prototypes correct. Use `const` and call by reference where appropriate. Make sure you label what parts of the class are `public` and `private`. Include prototypes for any related non-member functions. Save the implementation of all functions for the `customer.cpp` file, which is the next part.

Solution:

```
class Customer {
public:
  // CONSTRUCTOR
  Customer(const std::string& name);
  // ACCESSORS
  const std::string& getName() const;
  const std::string& getStylist() const;
  const Date& lastAppointment() const;
  int numAppointments() const;
  // MODIFIERS
  void hairCut(const Date &d,const std::string &stylist);
private:
  // REPRESENTATION
  std::string customer_name;
  std::string preferred_stylist;
  std::vector<Date> appointments;
};

// helper function for sorting
bool stylist_then_last_appointment(const Customer &c1, const Customer &c2);
```

5.2 `Customer` Class Implementation [/17]

Now implement the member functions and related non-member functions of the class, as they would appear in the corresponding `customer.cpp` file.

Solution:

```
// CONSTRUCTOR
Customer::Customer(const std::string &name) {
  customer_name = name;
}

// ACCESSORS
const std::string& Customer::getName() const {
  return customer_name;
}
const std::string& Customer::getStylist() const {
  return preferred_stylist;
}
const Date& Customer::lastAppointment() const {
  return appointments.back();
}
int Customer::numAppointments() const {
  return appointments.size();
}

// MODIFIER
void Customer::hairCut(const Date &d,const std::string &stylist) {
  if (stylist != preferred_stylist) {
    std::cout << "Setting " << stylist << " as " << customer_name << "'s preferred stylist." << std::endl;
    preferred_stylist = stylist;
  }
  appointments.push_back(d);
}
```

```
// COMPARISON FUNCTION FOR SORTING
bool stylist_then_last_appointment(const Customer &c1, const Customer &c2) {
  return (c1.getStylist() < c2.getStylist() ||
          (c1.getStylist() == c2.getStylist() && c1.lastAppointment() < c2.lastAppointment()));
}
```

6 Color Analysis of HW1 Images [/21]

Write a function named `color_analysis`, that takes three arguments: `image`, an STL `vector` of STL `string`s representing a rectangular ASCII image (similar to HW1); an integer `num_colors`; and a character `most_frequent_color`. The function scans through the image and returns (through the 2nd & 3rd arguments) the number of different colors (characters) in the image & the most frequently appearing color.

Solution:

```
void color_analysis(const std::vector<std::string> &image, int &num_colors, char &most_frequent_color) {
  // local variables to keep track of colors & counts
  std::vector<char> colors;
  std::vector<int> counts;
  // loop over every pixel in the image
  for (int i = 0; i < image.size(); i++) {
    for (int j = 0; j < image[i].size(); j++) {
      // add each pixel to the color counts
      bool found = false;
      for (int k = 0; k < colors.size() && !found; k++) {
        if (image[i][j] == colors[k]) {
          counts[k]++;
          found = true;
        }
      }
      // if we haven't seen this color before...
      if (!found) {
        colors.push_back(image[i][j]);
        counts.push_back(1);
      }
    }
  }
  // loop over all of the colors to find the most frequent
  int max_count = 0;
  for (int k = 0; k < colors.size(); k++) {
    if (max_count < counts[k]) {
      max_count = counts[k];
      most_frequent_color = colors[k];
    }
  }
  // also set the num_colors "return value"
  num_colors = colors.size();
}
```

What is the order notation of your solution in terms of w & h, the width & height of the image, and c, the number of different colors in the image?

Solution: $O(w * h * c)$**. This function is a simple triply-nested loop. Thus, the order notation is a product of the controlling variables for each loop.**

7 Power Matrix Construction [/16]

Write a function named `make_power_matrix` that takes in two arguments, `num_rows` and `num_columns`, and creates and returns a 2D matrix using STL `vectors`. Each element of the matrix $m_{r,c}$ stores the value r^c, that is, the row index raised to the power of the column index. For example, `make_power_matrix(5,7)` should produce this matrix:

```
1        0        0        0        0        0        0
1        1        1        1        1        1        1
1        2        4        8       16       32       64
```

```
1         3          9         27         81        243        729
1         4         16         64        256       1024       4096
```

Try to write this function *without using* the `pow` function.

Solution:

```
std::vector<std::vector<int> > make_power_matrix(int rows, int cols) {
  std::vector<std::vector<int> > answer;
  for (int r = 0; r < rows; r++) {
    std::vector<int> helper;
    int val = 1;
    for (int c = 0; c < cols; c++) {
      helper.push_back(val);
      val *= r;
    }
    answer.push_back(helper);
  }
  return answer;
}
```

What is the order notation of your solution in terms of r, the number of rows, and c, the number of columns?

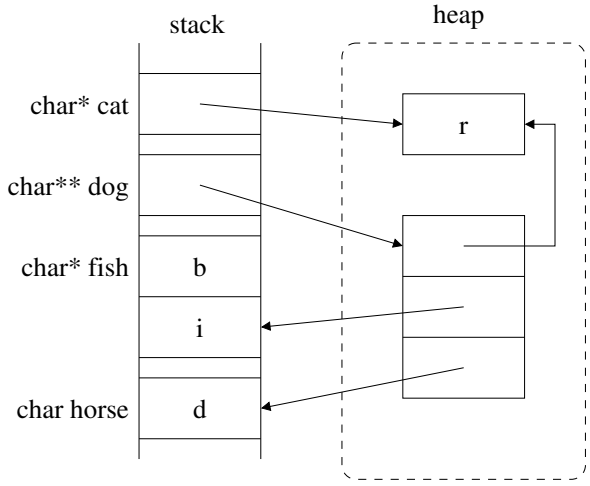
Solution: To create this 2D vector structure, it will cost $O(r * c)$. Note this is true either using the constructor that creates an array of a specific size or with push_back. Keeping a running product (multiplication) means that it is a constant amount of work per element, even without the `pow` function.

8 Diagramming Pointers & Memory [/15]

In this problem you will work with pointers and dynamically allocated memory. The fragment of code below allocates and writes to memory on both *the stack* and *the heap*. Following the conventions from lecture, draw a picture of the memory after the execution of the statements below.

```
char* cat;
char** dog;
char fish[2];
char horse;
dog = new char*[3];
dog[0] = new char;
fish[0] = 'b';
fish[1] = 'i';
dog[1] = &fish[1];
dog[2] = &horse;
cat = dog[0];
*cat = 'r';
horse = 'd';
```

Solution:



Now, write a fragment a C++ code that cleans up all dynamically allocated memory within the above example so that the program will not have a memory leak.

Solution:

```
delete [] dog;
delete cat;
```

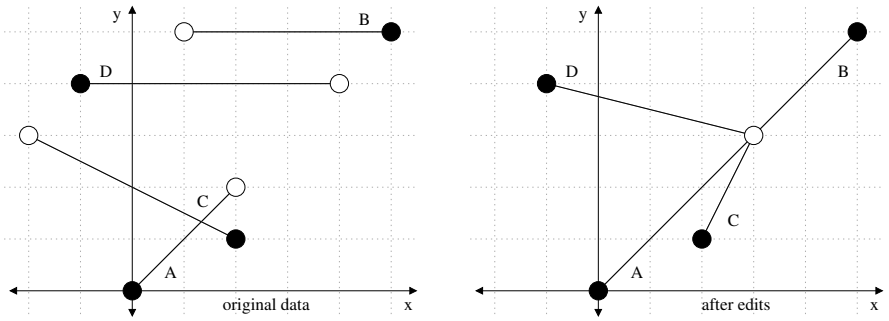
9 Classy Line Slopes [/28]

In this problem you will implement a simple class named `Line` to keep track of two dimensional lines. `Line`s are defined by two endpoints with integer coordinates. We will calculate the slope and y-axis intercept of each of the lines. Remember from algebra/geometry class that the equation for a line is $y = mx + b$, where m is the slope and b is the y-intercept. You may assume that the two endpoints are not the same point, and that the line is not exactly vertical (which would correspond to slope=∞).

In the example below we make four `Line` objects and put them in an STL `vector`. The diagram on the left shows the original position of each of the lines – the black dot is the "first" endpoint and the white dot is the "second" endpoint. The `Line` class allows us to edit the second endpoint of each line, as shown in the diagram on the right, and in the code below.

```
Line a ("A",   0, 0,   2, 2);
Line b ("B",   5, 5,   1, 5);
Line c ("C",   2, 1,  -2, 3);
Line d ("D",  -1, 4,   4, 4);

std::vector<Line> lines;
lines.push_back(a);
lines.push_back(b);
lines.push_back(c);
lines.push_back(d);
```



Here's a helper function that outputs information about each line stored in a `vector`:

```
void printLines(const std::vector<Line> &lines) {
  for (int i = 0; i < lines.size(); i++) {
    std::cout << "Line " << lines[i].getName()
              << std::fixed << std::setprecision(2)
              << " with slope=" << std::setw(5) << lines[i].getSlope()
              << " and y intercept=" << std::setw(5) << lines[i].getYIntercept()
              << std::endl;
  }
}
```

Here's a code fragment that will first sort the line collection by slope and then print the lines:

```
std::cout << "original data, sorted by slope" << std::endl;
sort(lines.begin(),lines.end(),by_slope);
printLines(lines);
```

Now we edit the second endpoint of each line to be the point (3,3) and then sort and print the data again:

```
for (int i = 0; i < lines.size(); i++) {
  lines[i].setNewSecondPoint(3,3);
}
std::cout << "after changing second point to (3,3)" << std::endl;
sort(lines.begin(),lines.end(),by_slope);
printLines(lines);
```

The code above results in this output to the screen:

```
original data, sorted by slope
Line C with slope=-0.50 and y intercept= 2.00
Line D with slope= 0.00 and y intercept= 4.00
Line B with slope= 0.00 and y intercept= 5.00
Line A with slope= 1.00 and y intercept= 0.00
after changing second point to (3,3)
Line D with slope=-0.25 and y intercept= 3.75
Line B with slope= 1.00 and y intercept= 0.00
Line A with slope= 1.00 and y intercept= 0.00
Line C with slope= 2.00 and y intercept=-3.00
```

9.1 `Line` Class Declaration [/13]

Using the sample code on the previous page as your guide, write the class declaration for the `Line` object. That is, write the *header file* (`line.h`) for this class. You don't need to worry about the `#include` lines or other pre-processor directives. Focus on getting the member variable types and member function prototypes correct. Use `const` and call by reference where appropriate. Make sure you label what parts of the class are `public` and `private`. Include prototypes for any related non-member functions. Save the implementation of all functions for the `line.cpp` file, which is the next part.

Solution:

```
class Line {
public:
  // CONSTRUCTOR
  Line(const std::string &name, int x1, int y1, int x2, int y2);
  // ACCESSORS
  float getSlope() const;
  float getYIntercept() const;
  const std::string& getName() const;
  // MODIFIERS
  void setNewSecondPoint(int x2, int y2);
private:
  // REPRESENTATION
  std::string name_;
  int x1_,y1_,x2_,y2_;
};

bool by_slope (const Line &a, const Line &b);
```

9.2 `Line` Class Implementation [/15]

Now implement the member functions and related non-member functions of the class, as they would appear in the corresponding `line.cpp` file.

Solution:

```
Line::Line(const std::string &name, int x1, int y1, int x2, int y2) {
  name_ = name;
  x1_=x1;
  y1_=y1;
  x2_=x2;
  y2_=y2;
  assert (x1_ != x2_);
}

const std::string& Line::getName() const {
  return name_;
}


float Line::getSlope() const {
  int rise = y2_-y1_;
  int run = x2_-x1_;
  return (float)rise/(float)run;
```

```
}

float Line::getYIntercept() const {
  float slope = getSlope();
  return y1_ - slope*x1_;
}

void Line::setNewSecondPoint(int x2, int y2) {
  x2_ = x2;
  y2_ = y2;
  assert (x1_ != x2_);
}

bool by_slope (const Line &a, const Line &b) {
  if (a.getSlope() < b.getSlope())
    return true;
  return false;
}
```

10 Common C++ Programming Errors [/12]

For each code fragment below, choose the letter that best describes the program error. *Hint: Each letter will be used exactly once.*

A) Uninitialized memory
B) Compile error: type mismatch
C) Accessing data beyond the array bounds
D) Infinite loop
E) Math error (incorrect answer)
F) Memory leak
G) Syntax error
H) Does not contain an error

F

```
float* floating_pt_ptr = new float;
*floating_pt_ptr = 5.3;
floating_pt_ptr = NULL;
```

H

```
int* apple;
int banana[5] = {1, 2, 3, 4, 5};
apple = &banana[2];
*apple = 6;
```

A

```
double x;
for (int i = 0; i < 10; i++) {
  x += sqrt(double(i));
}
```

E

```
float a = 2.0;
float b = -11.0;
float c = 12.0;
float pos_root =
  -b + sqrt(b*b - 4*a*c) / 2*a;
float neg_root =
  -b - sqrt(b*b - 4*a*c) / 2*a;
```

D

```
unsigned int x;
for (x = 10; x >= 0; x--) {
  std::cout << x << std::endl;
}
```

B

```
std::vector<std::string> temperature;
temperature.push_back(43.5);
```

G

```
int balance = 100;
int withdrawal;
std::cin >> withdrawal;
if (withdrawal <= balance)
  balance -= withdrawal;
  std::cout << "success\n";
else
  std::cout << "failure\n";
```

C

```
int grades[4] = { 1, 2, 3, 4 };
std::cout << "grades" << grades[1]
          << " " << grades[2]
          << " " << grades[3]
          << " " << grades[4]
          << std::endl;
```

11 Detecting Compound Words [/18]

Write a C++ function that takes in a collection of English words stored as an STL `vector` of STL `strings`. The function should return a `vector` containing all *compound words* from the input collection. We define a compound word as two or three words joined together to make a different word. For example, given the input collection:

```
a back backlog backwoods backwoodsman cat catalog
less log man none nonetheless ship the woods woodsman
```

Your function should return (in any order):

```
backlog backwoods backwoodsman catalog nonetheless woodsman
```

Solution:

```
std::vector<std::string> compound_detector(const std::vector<std::string> &words) {
  std::vector<std::string> answer;
  // loop over each word, testing to see if it is a compound word
  for (int w = 0; w < words.size(); w++) {
    bool found = false;
    for (int x = 0; !found && x < words.size(); x++) {
      for (int y = 0; !found && y < words.size(); y++) {
        // 2 word combinations
        if (words[w] == words[x]+words[y]) {
          answer.push_back(words[w]);
          found = true;
        }
        for (int z = 0; !found && z < words.size(); z++) {
          // 3 word combinations
          if (words[w] == words[x]+words[y]+words[z]) {
            answer.push_back(words[w]);
            found = true;
          }
        }
      }
    }
  }
  return answer;
}
```

If there are n words in the input, what is the order notation of your solution?

Solution: To create compound words built from 3 words, we need a triple-nested loop. To see if combination is in the original list, we need another loop. The code above is $O(n^4)$. Depending on how the code is structured, an additional loop may be necessary to avoid adding duplicates to the output, which may increase the order notation. We will learn other data structures would help improve the running time.