Course: ENSF614 – Fall 2025
Lab #: Lab 3
Instructor: Mahmood Moussavi
Students Name: John Zhou, Muhammad Ibrahim Khan
Submission Date: Oct 1st, 2025

I have been keeping all the files in github. I hope by providing this github link will help you a little bit.
https://github.com/JZ-Zhou-UofC/ENSF-614-assignment-repo

Exercise A

```
/*
*
*
File Name: circle.cpp
Assignment: Lab 3 Exercise A
*  Completed by: John Zhou, Ibrahim Khan
*  Submission Date: oct 1st, 2025
*/
#include <iomanip>
#include <iostream>

#include "circle.h"
using namespace std;



const double Circle::pi = 3.141592653589793;
// Constructor
Circle::Circle(double x, double y, double r, const char *name)
    : Shape(Point(x, y), name), radius(r) {}

double Circle::get_radius() const { return radius; }
void Circle::set_radius(double r) { radius = r; }
```

```
double Circle::area() const { return radius* radius*pi; }

double Circle::perimeter() const { return 2*pi * radius; }

void Circle::display() const {
  cout << "Circle Name: " << (getName()) << "\n";
  cout << fixed << setprecision(2);
  cout << "X-coordinate: " << getOrigin().getx() << "\n";
  cout << "Y-coordinate: " << getOrigin().gety() << "\n";
  cout << "Radius: " << radius << "\n";
  cout << "Area: " << area() << "\n";
  cout << "Perimeter: " << perimeter() << "\n";
}



/*
*
*
File Name: circle.h
Assignment: Lab 3 Exercise A
*  Completed by: John Zhou, Ibrahim Khan
*  Submission Date: oct 1st, 2025
*/
#ifndef CIRCLE_H
#define CIRCLE_H

#include "shape.h"

class Circle : virtual public Shape {
```

```
 private:
  double radius;

 public:
  static const double pi;
  Circle(double x, double y, double radius, const char* name);
  Circle(double r, const Point& pt, const char* n) : Shape(pt, n), radius(r) {}

  double get_radius() const;
  void set_radius(double r);

  virtual double area() const;
  virtual double perimeter() const;
  virtual void display() const;
};

#endif
```

```
/*
*
*
File Name: curveCut.cpp
Assignment: Lab 2 Exercise B
*  Completed by: John Zhou, Ibrahim Khan
*  Submission Date: Sept 24, 2025
*/
#include "curveCut.h"

#include <iomanip>
#include <iostream>
using namespace std;
CurveCut::CurveCut(double x, double y, double width, double length,
                double radius, const char* name)
   : Shape(Point(x, y), name),
     Rectangle(x, y, width, length, name),
     Circle(x, y, radius, name) {
  if (radius > std::min(width, length)) {
    cerr << "Error: radius must be <= min(width, length)" << endl;
    exit(EXIT_FAILURE);
  }
}



double CurveCut::area() const {
  return Rectangle::area() - 0.25 * Circle::area();
}
```

```
double CurveCut::perimeter() const {
  return Rectangle::perimeter() - 2 * Circle::get_radius() +
        0.5 * Circle::perimeter();
}

void CurveCut::display() const {
  cout << "CurveCut Name: " << getName() << "\n";
  cout << "X-coordinate: " << getOrigin().getx() << "\n";
  cout << "Y-coordinate: " << getOrigin().gety() << "\n";
  cout << "Width: " << get_side_a() << "\n";
  cout << "Length: " << get_side_b() << "\n";
  cout << "Radius of the cut: " << Circle::get_radius() << "\n";
}
```

```
/*
*
*
File Name: rectangle.cpp
Assignment: Lab 2 Exercise B
*  Completed by: John Zhou, Ibrahim Khan
*  Submission Date: Sept 24, 2025
*/
#ifndef CURVECUT_h
#define CURVECUT_h

#include "circle.h"
#include "rectangle.h"
class CurveCut : public Rectangle, Circle {
 public:
  CurveCut(double x, double y, double side_a, double side_b, double radius,
          const char* name);

  virtual double area() const override;
  virtual double perimeter() const override;
  virtual void display() const override;
};

#endif
```

```
/*
*
*
File Name: graphicsWorld.cpp
Assignment: Lab 2 Exercise B
*  Completed by: John Zhou, Ibrahim Khan
*  Submission Date: Sept 24, 2025
*/
#include "graphicsWorld.h"

#include <iostream>

#include "circle.h"
#include "curveCut.h"
#include "point.h"
#include "rectangle.h"
#include "square.h"

using namespace std;

void GraphicsWorld::run() {
  cout << "------------------------------------------------------\n";
  cout << "Author: John Zhou\n";
  cout << "------------------------------------------------------\n\n";

#if 1  // Change 0 to 1 to test Point
  cout << "\nTesting class Point:" << endl;

  Point m(6, 8);
```

```
  Point n(6, 8);
  n.setx(9);

  cout << "\nExpected to display the distance between m and n is: 3";
  cout << "\nThe distance between m and n is: " << m.distance(n);

  cout << "\nExpected second version of the distance function also print: 3";
  cout << "\nThe distance between m and n is again: " << Point::distance(m, n)
       << "\n";
#endif  // end of block to test Point

#if 1  // Change 0 to 1 to test Square
  cout << "\n\nTesting Functions in class Square:" << endl;

  Square s(5, 7, 12, "SQUARE - S");
  s.display();
#endif  // end of block to test Square

#if 1  // Change 0 to 1 to test Rectangle
  cout << "\nTesting Functions in class Rectangle:" << endl;

  Rectangle a(5, 7, 12, 15, "RECTANGLE A");
  a.display();

  Rectangle b(16, 7, 8, 9, "RECTANGLE B");
  b.display();

  double d = a.distance(b);
  cout << "\nDistance between rectangle a and b is: " << d << endl;
```

```
Rectangle rec1 = a;  // copy constructor
rec1.display();

cout << "\nTesting assignment operator in class Rectangle:" << endl;
Rectangle rec2(3, 4, 11, 7, "RECTANGLE rec2");
rec2.display();

rec2 = a;  // assignment operator
a.set_side_b(200);
a.set_side_a(100);

cout << "\nExpected to display the following values for object rec2:" << endl;
cout << "Rectangle Name: RECTANGLE A\n"
    << "X-coordinate: 5\n"
    << "Y-coordinate: 7\n"
    << "Side a: 12\n"
    << "Side b: 15\n"
    << "Area: 180\n"
    << "Perimeter: 54\n";
cout << "\nIf it doesn't, there is a problem with your assignment operator.\n"
    << endl;
rec2.display();

cout << "\nTesting copy constructor in class Rectangle:" << endl;
Rectangle rec3(a);
rec3.display();

a.set_side_b(300);
```

```
  a.set_side_a(400);

  cout << "\nExpected to display the following values for object rec3:" << endl;
  cout << "Rectangle Name: RECTANGLE A\n"
      << "X-coordinate: 5\n"
      << "Y-coordinate: 7\n"
      << "Side a: 100\n"
      << "Side b: 200\n"
      << "Area: 20000\n"
      << "Perimeter: 600\n";
  cout << "\nIf it doesn't, there is a problem with your copy constructor.\n"
      << endl;
  rec3.display();
#endif  // end of block to test Rectangle



#if 1
  cout << "\nTesting Functions in class Circle:" << endl;
  Circle c(3, 5, 9, "CIRCLE C");
  c.display();
  cout << "the area of " << c.getName() << " is: " << c.area() << endl;
  cout << "the perimeter of " << c.getName() << " is: " << c.perimeter()
      << endl;
  d = a.distance(c);
  cout << "\nThe distance between rectangle a and circle c is: " << d;

  CurveCut rc(6, 5, 10, 12, 9, "CurveCut rc");
  rc.display();
  cout << "the area of " << rc.getName() << " is: " << rc.area();
```

```
cout << "the perimeter of " << rc.getName() << " is: " << rc.perimeter();
d = rc.distance(c);
cout << "\nThe distance between rc and c is: " << d;
// Using array of Shape pointers:
Shape* sh[4];
sh[0] = &s;
sh[1] = &a;
sh[2] = &c;
sh[3] = &rc;
sh[0]->display();
cout << "\nthe area of " << sh[0]->getName() << "is: " << sh[0]->area();
cout << "\nthe perimeter of " << sh[0]->getName()
    << " is: " << sh[0]->perimeter();
sh[1]->display();
cout << "\nthe area of " << sh[1]->getName() << "is: " << sh[1]->area();
cout << "\nthe perimeter of " << sh[0]->getName()
    << " is: " << sh[1]->perimeter();
sh[2]->display();
cout << "\nthe area of " << sh[2]->getName() << "is: " << sh[2]->area();
cout << "\nthe circumference of " << sh[2]->getName()
    << " is: " << sh[2]->perimeter();
sh[3]->display();
cout << "\nthe area of " << sh[3]->getName() << "is: " << sh[3]->area();
cout << "\nthe perimeter of " << sh[3]->getName()
    << " is: " << sh[3]->perimeter();
cout << "\nTesting copy constructor in class CurveCut:" << endl;
CurveCut cc = rc;
cc.display();
cout << "\nTesting assignment operator in class CurveCut:" << endl;
```

```
  CurveCut cc2(2, 5, 100, 12, 9, "CurveCut cc2");
  cc2.display();
  cc2 = cc;
  cc2.display();
  // end of block to test CurveCut

#endif  // end of block to test array of pointer and polymorphism
}
```

```
/*
*
*
File Name: graphicsWorld.h
Assignment: Lab 2 Exercise B
*  Completed by: John Zhou, Ibrahim Khan
*  Submission Date: Sept 24, 2025
*/
#ifndef GRAPHICSWORLD_H
#define GRAPHICSWORLD_H

class GraphicsWorld {
public:
   void run();
};

#endif
```

```
/*
*
*
File Name: Lab2_exBmain.cpp
Assignment: Lab 2 Exercise B
*  Completed by: John Zhou, Ibrahim Khan
*  Submission Date: Sept 24, 2025
*/
#include "graphicsWorld.h"

int main() {
   GraphicsWorld gw;
   gw.run();
   return 0;
}
```

```
/*
*
*
File Name: point.cpp
Assignment: Lab 2 Exercise B
*  Completed by: John Zhou, Ibrahim Khan
*  Submission Date: Sept 24, 2025
*/
#include "point.h"
#include <iostream>
#include <iomanip>
#include <cmath>

using namespace std;



int Point::idCounter = 1000;
// Constructor
Point::Point(double x_val, double y_val) : x(x_val), y(y_val) {
   idCounter ++;
   id=idCounter;
}



// Getters
double Point::getx() const { return x; }
double Point::gety() const { return y; }
int Point::getId() const { return id; }
```

```
// Setters
void Point::setx(double x_val) { x = x_val; }
void Point::sety(double y_val) { y = y_val; }



void Point::display() const {
    cout << fixed << setprecision(2);
    cout << "X-coordinate: " << x << "\n";
    cout << "Y-coordinate: " << y << "\n";
}

int Point::counter() {
    return idCounter -1000;
}

double Point::distance(const Point& other) const {
    double dx = x - other.x;
    double dy = y - other.y;
    return sqrt(dx * dx + dy * dy);
}

// Static distance (between any two points)
double Point::distance(const Point& p1, const Point& p2) {
    double dx = p1.x - p2.x;
    double dy = p1.y - p2.y;
    return sqrt(dx * dx + dy * dy);
}
```

```
/*
*
*
File Name: point.h
Assignment: Lab 2 Exercise B
*  Completed by: John Zhou, Ibrahim Khan
*  Submission Date: Sept 24, 2025
*/
#ifndef POINT_H
#define POINT_H

class Point {
private:
   double x;
   double y;
   int id;
   static int idCounter; // Static member to track all ID

public:
   Point(double x_val, double y_val);

   // Getters
   double getx() const;
   double gety() const;
   int getId() const;

   // Setters
```

```
    void setx(double x_val);
    void sety(double y_val);

    void display() const;
    //static to access the static member
    static int counter();
    double distance(const Point& other) const;
    //This can be static because this does not require an object of point
    static double distance(const Point& p1, const Point& p2);
};

#endif
```

```
/*
*
*
File Name: rectangle.cpp
Assignment: Lab 2 Exercise B
*  Completed by: John Zhou, Ibrahim Khan
*  Submission Date: Sept 24, 2025
*/
#include "rectangle.h"
#include <iostream>
#include <iomanip>
using namespace std;

Rectangle::Rectangle(double x, double y, double side_a, double side_b, const char *name)
   : Shape(Point(x, y), name),Square(x, y, side_a, name), side_b(side_b) {}



double Rectangle::get_side_b() const
{
   return side_b;
}

void Rectangle::set_side_b(double side)
{
   side_b = side;
}

double Rectangle::area() const
{
```

```
    return get_side_a() * side_b;
}

double Rectangle::perimeter() const
{
    return 2 * (get_side_a() + side_b);
}

void Rectangle::display() const
{
    cout << "Rectangle Name: " << (getName()) << "\n";
    cout << fixed << setprecision(2);
    cout << "X-coordinate: " << getOrigin().getx() << "\n";
    cout << "Y-coordinate: " << getOrigin().gety() << "\n";
    cout << "Side a: " << get_side_a() << "\n";
    cout << "Side b: " << side_b << "\n";
    cout << "Area: " << area() << "\n";
    cout << "Perimeter: " << perimeter() << "\n";
}









/*
*
```

```
*
File Name: rectangle.cpp
Assignment: Lab 2 Exercise B
*  Completed by: John Zhou, Ibrahim Khan
*  Submission Date: Sept 24, 2025
*/
#ifndef RECTANGLE_H
#define RECTANGLE_H

#include "square.h"

class Rectangle :  public Square
{
private:
   double side_b;

public:
   Rectangle(double x, double y, double side_a, double side_b, const char *name);


   double get_side_b() const;
   void set_side_b(double side);

   virtual double area() const override;
   virtual double perimeter() const override;
   virtual void display() const override;
};

#endif
```

```
/*
*
*
File Name: shape.cpp
Assignment: Lab 2 Exercise B
*  Completed by: John Zhou, Ibrahim Khan
*  Submission Date: Sept 24, 2025
*/
#include "shape.h"
#include <iostream>
#include <cstring>
#include <cmath>
#include <iomanip>
using namespace std;

// Constructor
Shape::Shape(const Point& pt, const char* name) : origin(pt) {

      shapeName = new char[strlen(name) + 1];
      strcpy(shapeName, name);

}

Shape::Shape(const Shape& other) : origin(other.origin) {
   if (other.shapeName) {
      shapeName = new char[strlen(other.shapeName) + 1];
      strcpy(shapeName, other.shapeName);
   } else {
```

```
        shapeName = nullptr;
    }
}

// Assignment operator
Shape& Shape::operator=(const Shape& other) {
    if (this != &other) {
        origin = other.origin;

        delete[] shapeName;
        if (other.shapeName) {
            shapeName = new char[strlen(other.shapeName) + 1];
            strcpy(shapeName, other.shapeName);
        } else {
            shapeName = nullptr;
        }
    }
    return *this;
}
// Destructor
Shape::~Shape() {
    delete[] shapeName;
}

// Getters
const Point& Shape::getOrigin() const {
    return origin;
}
```

```
const char* Shape::getName() const {
    return shapeName;
}

void Shape::move(double dx, double dy) {
    origin.setx(origin.getx() + dx);
    origin.sety(origin.gety() + dy);
}



void Shape::display() const {
    cout << "Shape Name: " << (shapeName ? shapeName : "Unnamed") << "\n";
    cout << fixed << setprecision(2);
    cout << "X-coordinate: " << origin.getx() << "\n";
    cout << "Y-coordinate: " << origin.gety() << "\n";
}

double Shape::distance(Shape& other) {
    return origin.distance(other.getOrigin());
}



double Shape::distance(Shape& s1, Shape& s2) {
    return Point::distance(s1.getOrigin(), s2.getOrigin());
}
```

```
/*
*
*
File Name: shape.h
Assignment: Lab 2 Exercise B
*  Completed by: John Zhou, Ibrahim Khan
*  Submission Date: Sept 24, 2025
*/
#ifndef SHAPE_H
#define SHAPE_H

#include "point.h"

class Shape {
 protected:
  Point origin;
  char* shapeName;

 public:
  // shapeName is on heap
  // Constructor
  Shape(const Point& pt, const char* name);
  // Copy constructor
  Shape(const Shape& other);
  // Assignment operator
  Shape& operator=(const Shape& other);

  virtual ~Shape();
```

```
  // Getters
  const Point& getOrigin() const;
  const char* getName() const;

  void move(double dx, double dy);

  virtual void display() const;
  virtual double area() const = 0;
  virtual double perimeter() const = 0;
  double distance(Shape& other);
  // Static function, does not require shape object
  static double distance(Shape& s1, Shape& s2);
};

#endif
```

```
/*
*
*
File Name: square.cpp
Assignment: Lab 2 Exercise B
*  Completed by: John Zhou, Ibrahim Khan
*  Submission Date: Sept 24, 2025
*/
#include "square.h"

#include <iomanip>
#include <iostream>
using namespace std;

// Constructor
Square::Square(double x, double y, double side, const char* name)
    : Shape(Point(x, y), name), side_a(side) {}




double Square::get_side_a() const { return side_a; }
void Square::set_side_a(double side) { side_a = side; }

double Square::area() const { return side_a * side_a; }

double Square::perimeter() const { return 4 * side_a; }

void Square::display() const {
  cout << "Square Name: " << (getName()) << "\n";
```

```
  cout << fixed << setprecision(2);
  cout << "X-coordinate: " << getOrigin().getx() << "\n";
  cout << "Y-coordinate: " << getOrigin().gety() << "\n";
  cout << "Side a: " << side_a << "\n";
  cout << "Area: " << area() << "\n";
  cout << "Perimeter: " << perimeter() << "\n";
}
```

```
/*
```

```
*
*
File Name: square.h
Assignment: Lab 2 Exercise B
*  Completed by: John Zhou, Ibrahim Khan
*  Submission Date: Sept 24, 2025
*/
#ifndef SQUARE_H
#define SQUARE_H

#include "shape.h"

class Square : virtual public Shape {
 private:
  double side_a;

 public:
  // Constructor
  Square(double x, double y, double side, const char *name);

  double get_side_a() const;
  void set_side_a(double side);

  virtual double area() const;
  virtual double perimeter() const;
  virtual void display() const;
};

#endif
```

Screenshot:

```
john-desktop@John-desktop MINGW64 ~/OneDrive/Desktop/uofc/ENSF-614-assignment-repo/assignment3/EXA (main)
$ ./EXA

Testing Functions in class Circle:
Circle Name: CIRCLE C
X-coordinate: 3.00
Y-coordinate: 5.00
Radius: 9.00
Area: 254.47
Perimeter: 56.55
the area of CIRCLE C is: 254.47
the perimeter of CIRCLE C is: 56.55

The distance between rectangle a and circle c is: 2.83CurveCut Name: CurveCut rc
X-coordinate: 6.00
Y-coordinate: 5.00
Width: 10.00
Length: 12.00
Radius of the cut: 9.00
the area of CurveCut rc is: 56.38the perimeter of CurveCut rc is: 54.27
The distance between rc and c is: 3.00Square Name: SQUARE - S
X-coordinate: 5.00
Y-coordinate: 7.00
Side a: 12.00
Area: 144.00
Perimeter: 48.00

the area of SQUARE - Sis: 144.00
the perimeter of SQUARE - S is: 48.00Rectangle Name: RECTANGLE A
X-coordinate: 5.00
Y-coordinate: 7.00
Side a: 400.00
Side b: 300.00
Area: 120000.00
Perimeter: 1400.00

the area of RECTANGLE Ais: 120000.00
the perimeter of SQUARE - S is: 1400.00Circle Name: CIRCLE C
X-coordinate: 3.00
Y-coordinate: 5.00
Radius: 9.00
Area: 254.47
Perimeter: 56.55

the area of CIRCLE Cis: 254.47
the circumference of CIRCLE C is: 56.55CurveCut Name: CurveCut rc
X-coordinate: 6.00
Y-coordinate: 5.00
Width: 10.00
Length: 12.00
Radius of the cut: 9.00

the area of CurveCut rcis: 56.38
the perimeter of CurveCut rc is: 54.27
Testing copy constructor in class CurveCut:
CurveCut Name: CurveCut rc
X-coordinate: 6.00
Y-coordinate: 5.00
Width: 10.00
Length: 12.00
Radius of the cut: 9.00

Testing assignment operator in class CurveCut:
CurveCut Name: CurveCut cc2
X-coordinate: 2.00
Y-coordinate: 5.00
Width: 100.00
Length: 12.00
Radius of the cut: 9.00
CurveCut Name: CurveCut rc
X-coordinate: 6.00
Y-coordinate: 5.00
Width: 10.00
Length: 12.00
Radius of the cut: 9.00
```

Exercise C

```
// LookupTable.h
// ENSF 614 - Lab 3, Ex C (Templated Version)

#ifndef LOOKUPTABLE_H
#define LOOKUPTABLE_H
#include <cassert>
#include <iostream>
using namespace std;

// Forward declaration
template <typename Key, typename Datum>
class LookupTable;

template <typename Key, typename Datum>
struct Pair {
  Pair(Key keyA, Datum datumA) : key(keyA), datum(datumA) {}
  Key key;
  Datum datum;
};

// Node template
template <typename Key, typename Datum>
class LT_Node {
  friend class LookupTable<Key, Datum>;

 private:
  Pair<Key, Datum> pairM;
  LT_Node* nextM;
```

```
  LT_Node(const Pair<Key, Datum>& pairA, LT_Node* nextA);

  // LT_Node(const Pair<Key, Datum>& pairA, LT_Node* nextA): pairM(pairA), nextM(nextA) {};
};



// LookupTable template
template <typename Key, typename Datum>
class LookupTable {
 public:
  // Nested Iterator
  class Iterator {
    friend class LookupTable<Key, Datum>;
    LookupTable<Key, Datum>* LT;

   public:
    Iterator() : LT(0) {}
    Iterator(LookupTable<Key, Datum>& x) : LT(&x) {}
    const Datum& operator*();
    const Datum& operator++();
    const Datum& operator++(int);
    int operator!();
    void step_fwd() {
      assert(LT->cursor_ok());
      LT->step_fwd();
    }
  };
```

```
LookupTable();
LookupTable(const LookupTable& source);
LookupTable& operator=(const LookupTable& rhs);
~LookupTable();

LookupTable& begin();

int size() const;
int cursor_ok() const;

const Key& cursor_key() const;
const Datum& cursor_datum() const;

void insert(const Pair<Key, Datum>& pariA);
void remove(const Key& keyA);
void find(const Key& keyA);
void go_to_first();
void step_fwd();
void make_empty();

friend ostream& operator<<(ostream& os, const LookupTable<Key, Datum>& lt) {
  if (lt.cursor_ok())
    os << lt.cursor_key() << "  " << lt.cursor_datum();
  else
    os << "Not Found.";
  return os;
}
```

```
 private:
  int sizeM;
  LT_Node<Key, Datum>* headM;
  LT_Node<Key, Datum>* cursorM;

  void destroy();
  void copy(const LookupTable& source);
};

//  implementation
template <typename Key, typename Datum>
LT_Node<Key, Datum>::LT_Node(const Pair<Key, Datum>& pairA, LT_Node* nextA)
    : pairM(pairA), nextM(nextA) {}
template <typename Key, typename Datum>
LookupTable<Key, Datum>& LookupTable<Key, Datum>::begin() {
  cursorM = headM;
  return *this;
}

template <typename Key, typename Datum>
LookupTable<Key, Datum>::LookupTable() : sizeM(0), headM(0), cursorM(0) {}

template <typename Key, typename Datum>
LookupTable<Key, Datum>::LookupTable(const LookupTable& source) {
  copy(source);
}

template <typename Key, typename Datum>
LookupTable<Key, Datum>& LookupTable<Key, Datum>::operator=(
```

```
    const LookupTable& rhs) {
  if (this != &rhs) {
    destroy();
    copy(rhs);
  }
  return *this;
}

template <typename Key, typename Datum>
LookupTable<Key, Datum>::~LookupTable() {
  destroy();
}

template <typename Key, typename Datum>
int LookupTable<Key, Datum>::size() const {
  return sizeM;
}

template <typename Key, typename Datum>
int LookupTable<Key, Datum>::cursor_ok() const {
  return cursorM != 0;
}

template <typename Key, typename Datum>
const Key& LookupTable<Key, Datum>::cursor_key() const {
  assert(cursor_ok());
  return cursorM->pairM.key;
}
```

```
template <typename Key, typename Datum>
const Datum& LookupTable<Key, Datum>::cursor_datum() const {
  assert(cursor_ok());
  return cursorM->pairM.datum;
}

template <typename Key, typename Datum>
void LookupTable<Key, Datum>::insert(const Pair<Key, Datum>& pairA) {
  if (headM == 0 || pairA.key < headM->pairM.key) {
    headM = new LT_Node<Key, Datum>(pairA, headM);
    sizeM++;
  } else if (pairA.key == headM->pairM.key)
    headM->pairM.datum = pairA.datum;
  else {
    LT_Node<Key, Datum>* before = headM;
    LT_Node<Key, Datum>* after = headM->nextM;

    while (after != NULL && (pairA.key > after->pairM.key)) {
      before = after;
      after = after->nextM;
    }
    if (after != NULL && pairA.key == after->pairM.key) {
      after->pairM.datum = pairA.datum;
    } else {
      before->nextM = new LT_Node<Key, Datum>(pairA, before->nextM);
      sizeM++;
    }
  }
}
```

```
template <typename Key, typename Datum>
void LookupTable<Key, Datum>::remove(const Key& keyA) {
  if (headM == 0 || keyA < headM->pairM.key) return;

  LT_Node<Key, Datum>* doomed_node = 0;
  if (keyA == headM->pairM.key) {
    doomed_node = headM;
    headM = headM->nextM;
    sizeM--;
  } else {
    LT_Node<Key, Datum>* before = headM;
    LT_Node<Key, Datum>* maybe_doomed = headM->nextM;
    while (maybe_doomed != 0 && keyA > maybe_doomed->pairM.key) {
      before = maybe_doomed;
      maybe_doomed = maybe_doomed->nextM;
    }
    if (maybe_doomed != 0 && maybe_doomed->pairM.key == keyA) {
      doomed_node = maybe_doomed;
      before->nextM = maybe_doomed->nextM;
      sizeM--;
    }
  }
  delete doomed_node;
}

template <typename Key, typename Datum>
void LookupTable<Key, Datum>::find(const Key& keyA) {
  LT_Node<Key, Datum>* ptr = headM;
```

```
  while (ptr != NULL && ptr->pairM.key != keyA) {
    ptr = ptr->nextM;
  }
  cursorM = ptr;
}

template <typename Key, typename Datum>
void LookupTable<Key, Datum>::go_to_first() {
  cursorM = headM;
}

template <typename Key, typename Datum>
void LookupTable<Key, Datum>::step_fwd() {
  assert(cursor_ok());
  cursorM = cursorM->nextM;
}

template <typename Key, typename Datum>
void LookupTable<Key, Datum>::make_empty() {
  destroy();
  sizeM = 0;
  cursorM = 0;
}

template <typename Key, typename Datum>
void LookupTable<Key, Datum>::destroy() {
  LT_Node<Key, Datum>* ptr = headM;
  while (ptr != NULL) {
    headM = headM->nextM;
```

```
    delete ptr;
    ptr = headM;
  }
  cursorM = NULL;
  sizeM = 0;
}

template <typename Key, typename Datum>
void LookupTable<Key, Datum>::copy(const LookupTable& source) {
  headM = 0;
  cursorM = 0;
  if (source.headM == 0) return;

  for (LT_Node<Key, Datum>* p = source.headM; p != 0; p = p->nextM) {
    insert(Pair<Key, Datum>(p->pairM.key, p->pairM.datum));
    if (source.cursorM == p) find(p->pairM.key);
  }
}

// ------------ Iterator Implementation ---------------

template <typename Key, typename Datum>
const Datum& LookupTable<Key, Datum>::Iterator::operator*() {
  assert(LT->cursor_ok());
  return LT->cursor_datum();
}

template <typename Key, typename Datum>
const Datum& LookupTable<Key, Datum>::Iterator::operator++() {
```

```
  assert(LT->cursor_ok());
  const Datum& x = LT->cursor_datum();
  LT->step_fwd();
  return x;
}

template <typename Key, typename Datum>
const Datum& LookupTable<Key, Datum>::Iterator::operator++(int) {
  assert(LT->cursor_ok());
  LT->step_fwd();
  return LT->cursor_datum();
}

template <typename Key, typename Datum>
int LookupTable<Key, Datum>::Iterator::operator!() {
  return (LT->cursor_ok());
}

#endif
```

```
// ENSF 614 - Lab 3, Ex C
// M. Moussavi

#include <assert.h>
#include <iostream>
#include "lookupTable.h"
#include "customer.h"
#include "mystring2.h"
#include <cstring>
using namespace std;



template <typename K, typename V>
void print(LookupTable<K, V>& lt)
{
   if (lt.size() == 0)
      cout << "  Table is EMPTY.\n";
   for (lt.go_to_first(); lt.cursor_ok(); lt.step_fwd()) {
      cout << lt << endl;
   }
}

template <typename K, typename V>
void try_to_find(LookupTable<K, V>& lt, K key)
{
   lt.find(key);
   if (lt.cursor_ok())
      cout << "\nFound key:"  << lt;
```

```
    else
        cout << "\nSorry, I couldn't find key: " << key << " in the table.\n";
}

// TEST
void test_Customer()
{
    cout<<"\nCreating and testing Customers Lookup Table <int, Customer>...\n";
    LookupTable<int, Customer> lt;

    // Insert using new keys.
    Customer a("Joe", "Morrison", "11 St. Calgary.", "(403)-1111-123333");
    Customer b("Jack", "Lewis", "12 St. Calgary.", "(403)-1111-123334");
    Customer c("Tim", "Hardy", "13 St. Calgary.", "(403)-1111-123335");
    lt.insert(Pair<int, Customer>(8002, a));
    lt.insert(Pair<int, Customer>(8004, c));
    lt.insert(Pair<int, Customer>(8001, b));

    assert(lt.size() == 3);
    lt.remove(8004);
    assert(lt.size() == 2);
    cout << "\nPrinting table after inserting 3 new keys and 1 removal...\n";
    print(lt);

    // Pretend that a user is trying to look up customers info.
    cout << "\nLet's look up some names ...\n";
    try_to_find(lt, 8001);
    try_to_find(lt, 8000);
```

```
// test Iterator
cout << "\nTesting and using iterator ...\n";
typename LookupTable<int, Customer>::Iterator it = lt.begin();
cout <<"\nThe first node contains: " << *it << endl;

while (!it) {
   cout << ++it << endl;
}

// test copying
lt.go_to_first();
lt.step_fwd();
LookupTable<int, Customer> clt(lt);
assert(strcmp(clt.cursor_datum().getFname(), "Joe") == 0);

cout << "\nTest copying: keys should be 8001, and 8002\n";
print(clt);
lt.remove(8002);

// Assignment operator check.
clt = lt;
cout << "\nTest assignment operator: key should be 8001\n";
print(clt);

// Wipe out the entries in the table.
lt.make_empty();
cout << "\nPrinting table for the last time: Table should be empty...\n";
print(lt);
```

```
    cout << "***----Finished tests on Customers Lookup Table <int, Customer>-----***\n";
    cout << "PRESS RETURN TO CONTINUE.";
    cin.get();
}

void test_String()
{
    cout<<"\nCreating and testing LookupTable <int, Mystring> .....\n";
    LookupTable<int, Mystring> lt;

    // Insert using new keys.
    Mystring a("I am an ENEL-409 student.");
    Mystring b("C++ is a powerful language for engineers but it's not easy.");
    Mystring c("Winter 2004");

    lt.insert(Pair<int, Mystring>(8002,a));
    lt.insert(Pair<int, Mystring>(8001,b));
    lt.insert(Pair<int, Mystring>(8004,c));

    cout << "\nPrinting table after inserting 3 new keys...\n";
    print(lt);

    // Pretend that a user is trying to look up customers info.
    cout << "\nLet's look up some names ...\n";
    try_to_find(lt, 8001);
    try_to_find(lt, 8000);

    // test Iterator
    typename LookupTable<int, Mystring>::Iterator it = lt.begin();
```

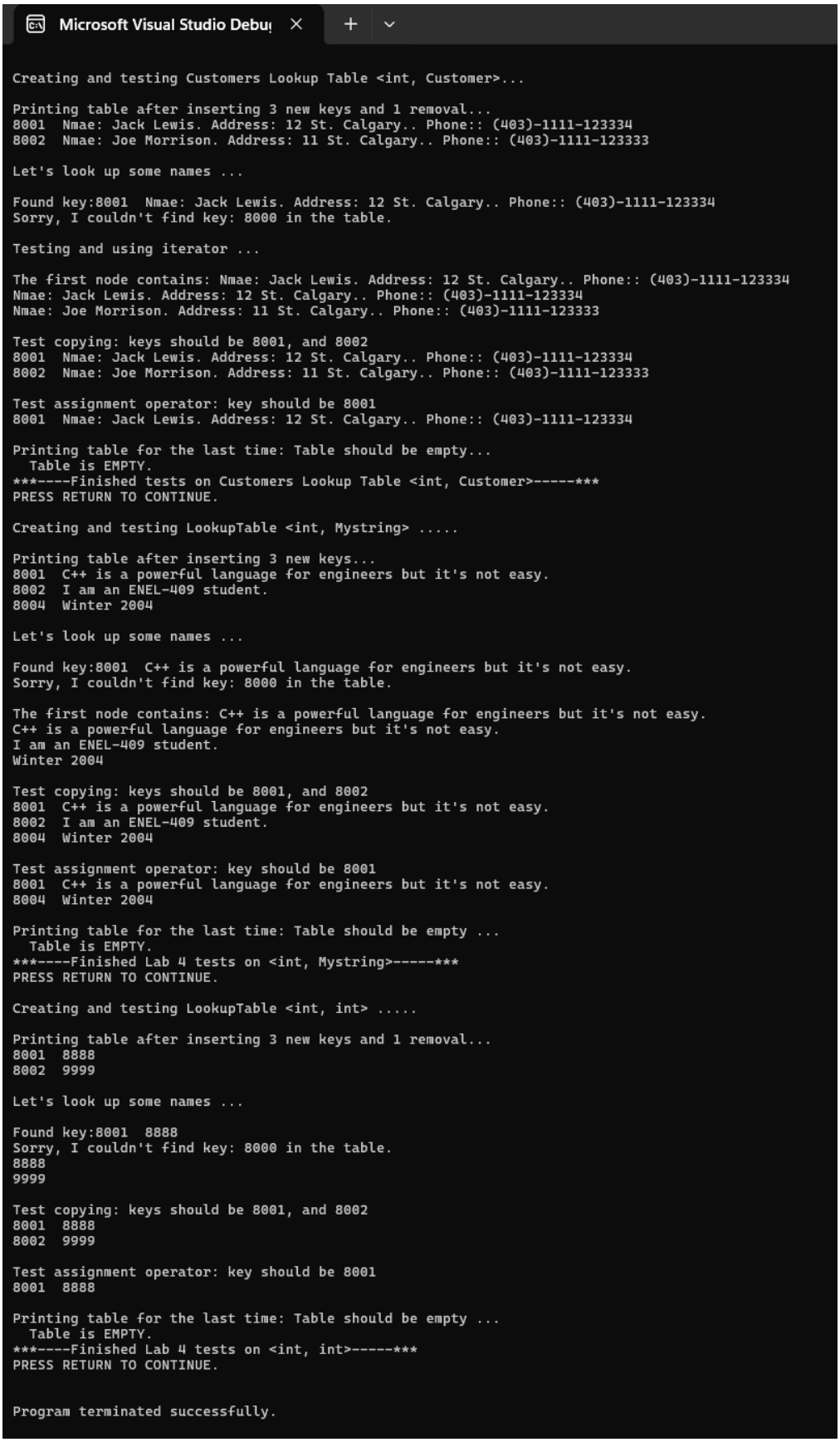
```
cout <<"\nThe first node contains: " << *it << endl;

while (!it) {
   cout << ++it << endl;
}

// test copying
lt.go_to_first();
lt.step_fwd();
LookupTable<int, Mystring> clt(lt);
assert(strcmp(clt.cursor_datum().c_str(), "I am an ENEL-409 student.") == 0);

cout << "\nTest copying: keys should be 8001, and 8002\n";
print(clt);
lt.remove(8002);

// Assignment operator check.
clt = lt;
cout << "\nTest assignment operator: key should be 8001\n";
print(clt);

// Wipe out the entries in the table.
lt.make_empty();
cout << "\nPrinting table for the last time: Table should be empty ...\n";
print(lt);

cout << "***----Finished Lab 4 tests on <int, Mystring>-----***\n";
cout << "PRESS RETURN TO CONTINUE.";
cin.get();
```

```
}

void test_integer()
{
   cout<<"\nCreating and testing LookupTable <int, int> .....\n";
   LookupTable<int, int> lt;

   // Insert using new keys.
   lt.insert(Pair<int, int>(8002,9999));
   lt.insert(Pair<int, int>(8001,8888));
   lt.insert(Pair<int, int>(8004,8888));
   assert(lt.size() == 3);
   lt.remove(8004);
   assert(lt.size() == 2);
   cout << "\nPrinting table after inserting 3 new keys and 1 removal...\n";
   print(lt);

   // Pretend that a user is trying to look up customers info.
   cout << "\nLet's look up some names ...\n";
   try_to_find(lt, 8001);
   try_to_find(lt, 8000);

   // test Iterator
   typename LookupTable<int, int>::Iterator it = lt.begin();

   while (!it) {
      cout << ++it << endl;
   }
```

```
    // test copying
    lt.go_to_first();
    lt.step_fwd();
    LookupTable<int, int> clt(lt);
    assert(clt.cursor_datum() == 9999);

    cout << "\nTest copying: keys should be 8001, and 8002\n";
    print(clt);
    lt.remove(8002);

    // Assignment operator check.
    clt = lt;
    cout << "\nTest assignment operator: key should be 8001\n";
    print(clt);

    // Wipe out the entries in the table.
    lt.make_empty();
    cout << "\nPrinting table for the last time: Table should be empty ...\n";
    print(lt);

    cout << "***----Finished Lab 4 tests on <int, int>-----***\n";
    cout << "PRESS RETURN TO CONTINUE.";
    cin.get();
}

// ====================== MAIN =====================
int main()
{
    test_Customer();  // LookupTable<int, Customer>
```

```
    test_String();    // LookupTable<int, Mystring>
    test_integer();   // LookupTable<int, int>

    cout<<"\n\nProgram terminated successfully.\n\n";
    return 0;
}
```

Screenshot


Microsoft Visual Studio Debu
Creating and testing Customers Lookup Table <int, Customer>...
Printing table after inserting 3 new keys and 1 removal...
8001 Nmae: Jack Lewis. Address: 12 St. Calgary.. Phone:: (403)-1111-123334
8002 Nmae: Joe Morrison. Address: 11 St. Calgary.. Phone:: (403)-1111-123333
Let's look up some names ...
Found key:8001 Nmae: Jack Lewis. Address: 12 St. Calgary.. Phone:: (403)-1111-123334
Sorry, I couldn't find key: 8000 in the table.
Testing and using iterator ...
The first node contains: Nmae: Jack Lewis. Address: 12 St. Calgary.. Phone:: (403)-1111-123334
Nmae: Jack Lewis. Address: 12 St. Calgary.. Phone:: (403)-1111-123334
Nmae: Joe Morrison. Address: 11 St. Calgary.. Phone:: (403)-1111-123333
Test copying: keys should be 8001, and 8002
8001 Nmae: Jack Lewis. Address: 12 St. Calgary.. Phone:: (403)-1111-123334
8002 Nmae: Joe Morrison. Address: 11 St. Calgary.. Phone:: (403)-1111-123333
Test assignment operator: key should be 8001
8001 Nmae: Jack Lewis. Address: 12 St. Calgary.. Phone:: (403)-1111-123334
Printing table for the last time: Table should be empty...
Table is EMPTY.
-----Finished tests on Customers Lookup Table <int, Customer>------
PRESS RETURN TO CONTINUE.
Creating and testing LookupTable <int, Mystring> .....
Printing table after inserting 3 new keys...
8001 C++ is a powerful language for engineers but it's not easy.
8002 I am an ENEL-409 student.
8004 Winter 2004
Let's look up some names ...
Found key:8001 C++ is a powerful language for engineers but it's not easy.
Sorry, I couldn't find key: 8000 in the table.
The first node contains: C++ is a powerful language for engineers but it's not easy.
C++ is a powerful language for engineers but it's not easy.
I am an ENEL-409 student.
Winter 2004
Test copying: keys should be 8001, and 8002
8001 C++ is a powerful language for engineers but it's not easy.
8002 I am an ENEL-409 student.
8004 Winter 2004
Test assignment operator: key should be 8001
8001 C++ is a powerful language for engineers but it's not easy.
8004 Winter 2004
Printing table for the last time: Table should be empty ...
Table is EMPTY.
-----Finished Lab 4 tests on <int, Mystring>------
PRESS RETURN TO CONTINUE.
Creating and testing LookupTable <int, int> .....
Printing table after inserting 3 new keys and 1 removal...
8001 8888
8002 9999
Let's look up some names ...
Found key:8001 8888
Sorry, I couldn't find key: 8000 in the table.
8888
9999
Test copying: keys should be 8001, and 8002
8001 8888
8002 9999
Test assignment operator: key should be 8001
8001 8888
Printing table for the last time: Table should be empty ...
Table is EMPTY.
-----Finished Lab 4 tests on <int, int>------
PRESS RETURN TO CONTINUE.
Program terminated successfully.