

2143 - OOP
Spring 2021
Take Home Exam
April 22, 2021

Name: Ethan Coyle

READ THESE INSTRUCTIONS

- D Create a digital document (PDF) that has zero handwriting on it. Print and bring to the final exam on *Tuesday April 27th from 8:00 am - 10:00am.*
- D Your presentation and thoroughness of answers is a large part of your grade. Presentation means: use examples when you can, graphics or images, and organize your answers!
- D I make every effort to create clear and understandable questions. You should do the same with your answers.
- D Questions should be answered in order and clearly marked.
- D Your name should be on each page, in the heading if possible.
- D Place your PDF on GitHub (after you take the actual final) and in your assignments folder.
- D Create a folder called **TakeHomeExam** and place your document in there. Name the actual document: **exam.pdf** within the folder.

Failure to comply with any of these rules will result in a NO grade. This is a courtesy exam to help you solidify your grade.

Grade Table (don't write on it)

Question	Points	Score
1	70	
2	15	
3	40	
4	10	
5	15	
6	10	
7	10	
8	20	
9	15	
10	20	
11	35	
12	10	
13	10	

Total:	280	
--------	-----	--

Warning: Support each and every answer with details. I do not care how mundane the question is ... justify your answer. Even for a question as innocuous or simple as "What is your name?", you should be very thorough when answering:

What is your name?: My name is Attila. This comes from the ancient figure "Attila the Hun". He was the leader of a tribal empire consisting of Huns, Ostrogoths, Alans and Bulgars, amongst others, in Central and Eastern Europe. My namesake almost conquered western Europe, but his brother died and he decided to go home. Lucky for us! We would all be speaking a mix of Asiatic dialects :)

Single word answers, and in fact single sentence answers will be scored with a zero. This is a take-home exam to help study for the final and boost your grade. Work on it accordingly.

1. This VS That. Not so simple answers Ç:

- (a) (7 points) Explain the difference between a *struct* and a *class*. Can one do whatever the other does?

There are a few differences between a structure and a class. The data that is inside of a structure is public by default and can be accessed throughout the project. The data that is inside of a class is private by default meaning that it can only be accessed inside the class and not outside. A class hides the implementation from the user. The implementation of a structure is not secure and doesn't hide the complexity of the implementation from the user. A class uses private inheritance and the structure uses public inheritance within its implementation. While they are similar, a class is the building blocks of creating an object in C++. A structure is basic blueprint in a group of variables that creates an object and does not use a key word to be declared. When the user creates multiple structures, it does not change the value of the created structure instead creates a new instance (like creating a structure to hold a person name, grade, age, and height). In addition, it can also be evaluate that a class is that it is an abstract data type that includes both function methods and data members. A structure

A class is the definition of an Abstract Data Type (ADT) which includes methods and data members.

- (b) (7 points) What is the difference between a *class* and an *object*?

A class is the building blocks of creating an object and all its component. This serves as the basic building block of the actual creation of an object (like building a car with a color, type and size) The object is the actual object that is created using that blueprint that is implemented by the class itself.

(c) (7 points) What is the difference between *inheritance* and *composition*?

Which one should you lean towards when designing your solution to a problem?

Inheritance in c++ is the process in which an object acquires all the properties

and the stated behaviours that are associated with that. This is particularly useful when the

user wants to modify certain things inside another class but still keep the original without modification. Composition of one or more of the objects of a certain class have a relationship with other classes. An example of this is a string object. (One thing is composed of another). Composition indicates that it has a “has-a” relationship between objects. Inheritance, indicates an “is-a” relationship that you lean toward using composition over inheritance.

(7 points) What is the difference between a *deep* vs a *shallow* copy? What can you do to make one or the other happen?

A deep copy copies all the fields of an object and makes a copy of it to a dynamically allocated memory spot with a pointer pointing to them. To create a deep copy, one must write a copy constructor and an overloaded assignment operator or else, it will be self assigned and that is a very bad bad thing.

A Shallow copy is similar to deep copy in the assignment of each member of an object to that of another object, but it differs in the manner in which the field of reference type is copied. This is best to use if you are copying an object to another object and you aren't trying to constantly change the object. This is accessed through the address referencing. The big difference between the two is that a deep copy is a pointer to type and the shallow copy is a pointer to address type. However, it is best to utilize the deep copy constructor if there is a lot of changes being made. Shallow copying is more efficient where object referencing allows the objects to be passed around by address and the entire object doesn't need to be copied.

(d) (7 points) What is the difference between a *constructor* and a *destructor*? Are they both mandatory or even necessary?

There are many types of a constructor inside of a class. These include a copy constructor, a default constructor and overloaded constructor. The constructor is base level responsible for creating a things such as default value for a class variable or if the user wants to overload the constructor, then an overloaded constructor is used to assign the user defined value to be the new values of that inside of the class. A destructors main job is to destroy the object. This is mainly used in larger projects and not so much in small based projects where not a lot of overloading or assignments are being done. But the destructoys the instance of that variable and begins anew. The compiler automatically creates a default constructor if one is not provided but in the case of both of these, it is best to add these inside especially the constructor to create instance of the variable or object in question and assign it values or a default value.

- (e) (7 points) What is *static* vs *dynamic* typing? Which does C++ employ and which does Python employ?

Static typing refers to when certina data types need to be initialized and be static at tun time. This basically implies that they need to be setup to run at compilation of programs and cannot change thie value without specific instructions inside of the code blocks and program itself. These static typing types are usually cast in the program. A language is also known to be statically typed if variable types are known at ompile time Meaning that the type must be identified for each variable. This is the case in C++.

A language is considered to be dynamically typed if the types that are associated with the runtime value and variables . This basically means that a a programmer can write quicker when writing code because they do not have to announce what type their variables and other types are every single time. This is a huge component of the Python language.

- (7 points) What is *encapsulation* vs *abstraction*? Please give some examples!

(Abstraction is in the design and encapsulation is in the implementation.)Abstraction hides the background details and emphasizes the essential data points for reducing the complexity and increase efficiency of the running of a program.An example of encapsulation is like taking a picture with a smartphone.The user does not need to understand how the smartphone process all the internal functions from taking the picture to creating the actual image by hiding all the unnecessary detail from the

user.Encapsulation is also implemented during during the Implementation level and focuses mainly on how it should be done. Whereas the Abstraction is implemented at the design level focuses on what should be done.

- (f) (7 points) What is the difference between an *abstract class* and an *interface*?

An Interface can have only abstract methods. An abstract class can have abstract and non-abstract methods when utilized. An abstract class will allow other classes to inherit directly from it but it is not able to create and instance of itself. The only functionality of an abstract class is allow other subclasses to inherit from it. An interface is basically like an empty template. An interface t contains methods without a formal signature or body but it cannot do anything by itself It is basically an empty tempalet that you can copied to and filled. It is also used to provide hierarchies and guidelines for other subclasses.

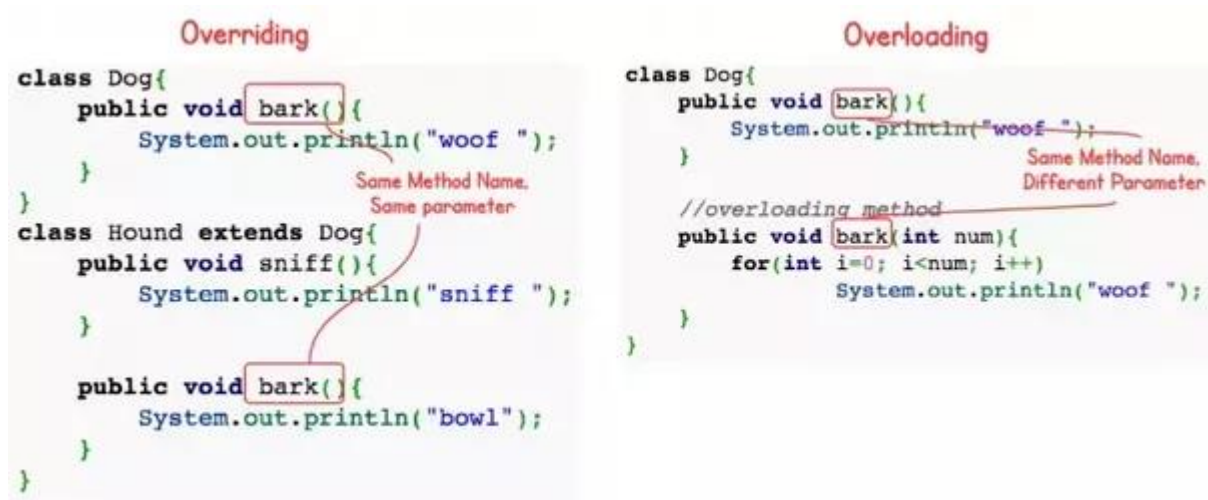
Abstract Class	Interface
An Abstract class doesn't provide full abstraction	Interface does provide full abstraction
Using Abstract we can not achieve multiple inheritance	using an Interface we can achieve multiple inheritance.
We can declare a member field	We can not declare a member field in an Interface
An abstract class can contain access modifiers for the subs, functions, properties	We can not use any access modifier i.e. public , private , protected , internal etc. because within an interface by default everything is public
An abstract class can be defined	An Interface member cannot be defined using the keyword static, virtual, abstract or sealed
A class may inherit only one abstract class.	A class may inherit several interfaces.
An abstract class can provide complete, default code and/or just the details that have to be overridden.	An interface cannot provide any code, just the signature.

- (g) (7 points) What is the difference between a *virtual function* and a *pure virtual function*?

A virtual function is a function that allows a program to call methods that don't really "exist upon compilation. This also refers to the inheritable and functions that are able to be overridden in which are dynamically dispatched. A pure virtual function is a function that acts as a sort of placeholder for other variabls and takes info from outside itself like other functions and other classes to fill in blank spaces. A huge advantage of using a pur virtual function is that information I very easily malleable and the different people utilizing it can change it according to their own needs. The only way that this will work it

that there must be some class in which it is derived from where the data can be acquired from. By it standing alone, this is useless. An example of the use of a virtual function is one in which asks for certain information from the user. The program will then go through the program and change (name or variable value etc to fit that users needs)

(h) (7 points) What is the difference between *Function Overloading* and *Function Overriding*?



Function overloading is a feature in C++ where two or more functions can have the same name but different parameters. When a function name is overloaded with different tasks that it needs to accomplish, like reading a user input and changing the default values, it is called Function Overloading. When a function that is being used in c++, it can have the same names but one functions parameters cannot be identical to the next(i.e a default versus another function with the same name but with two parameters.)Function overloading can also be seen to have the same concept and take on the form of polymorphism.

Function overing is basically a feature that allows a child and the inherited class member to have the same function name at the same time without any overlaps. A child class will inherit the data member and the functions of the parent class. However, when the user would like to override the functionality inside of the child class, then that is where function overriding comes in to play. This essentially is like

creating a newer version that is derived from the original inside of the child class. Below is an example of this feature.

To override a function you must have the same signature in child class. By signature I mean the data type and sequence of parameters. Here we don't have any parameter in the parent function so we didn't use any parameter in the child function.

```
#include <iostream>
using namespace std;
class BaseClass {
public:
    void disp(){
        cout<<"Function of Parent Class";
    }
};
class DerivedClass: public BaseClass{
public:
    void disp() {
        cout<<"Function of Child Class";
    }
};
int main() {
    DerivedClass obj = DerivedClass();
    obj.disp();
    return 0;
}
```

Output:

```
Function of Child Class
```

2. Define the following and give examples of each :

- (a) (5 points) Polymorphism
 - (b) (5 points) Encapsulation
 - (c) (5 points) Abstraction
-

Pillar of OOPS

- ▶ **Data Abstraction**(Data hide)
- ▶ **Inheritance.** (Reusability)
- ▶ **Polymorphism.** (Object to take many forms)
- ▶ **Encapsulation.** (Data hide)

Polymorphism is the the ability of an object to take several forms. This is a term that describes the basic principle in which different classes are able to be used withing the system and provide their own individual implementation. (many forms) some examples of polymorphism include function overloading , function over ridding and virtual functions.

Encapsulation is a process that combines data member and functions together into a single item which is referred to more commonly as class, which in turn prevents direct access to this data Although, access to these items and data members are done through the functions of those classes.

abstraction in C++ is the creation of a functionality of a created class, but details that are unnecessary are not shown to the user. The details using abstraction are intentionally hidden from the user because some of them are unesseary for the user to see.

3. (a) (5 points) What is a default constructor?

A default constructor is inside of a class declaration. A default constructors main purpose is to provide default values to the variables and parameters inside of the class. It is useful to have a default constructor instead of not having one. However, if the user does not define a default constructor, the system will automatically assign default values which more chances than not are not the ones the user wants.

Default Arguments with Constructors

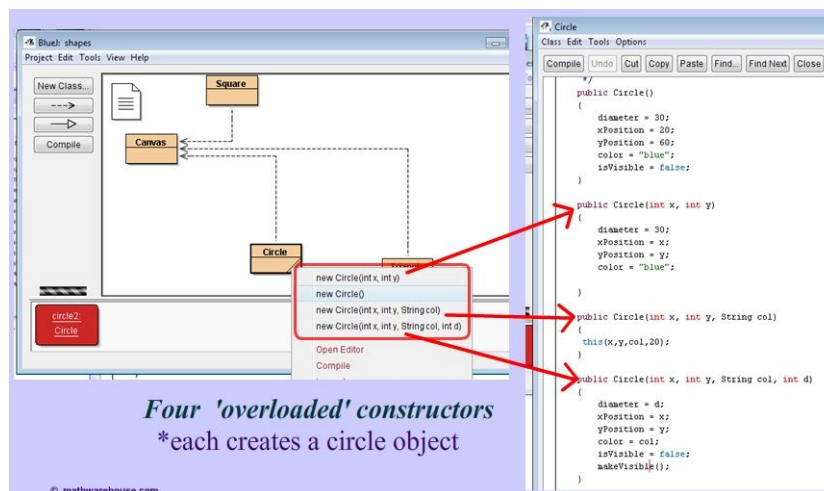
A default value can be specified in the constructor header using inline code

```
class Rectangle
{
    private:
        double width;
        double length;
    public:
        Rectangle();
        Rectangle::Rectangle(double w, double l=100)
        {
            width = w;
            length = l;
        }
};

// Which is the called in main by Rectangle box (rectWidth);
```

- (b) (5 points) What is an overloaded constructor? And is there a limit to the number of overloaded constructors you can have?

Overloaded constructors are constructors inside of a declared class that can have the same name, but pass through them different number of parameters. The constructors cannot be the same or pass the same values like (constructor(int)) and then declaring another constructor called (int). This will cause a compilation error due to the compiler not knowing which one to call. Also, depending on the number and the type of args that are passed inside of the program, the correspond constructor will be called and utilized. There is not a limit to the ammount of overloaded constructors that you can have inside of a class as long as no two constructors are identitcal.



- (c) (5 points) What is a copy constructor? Do you need to create a copy constructor for every class you define?

A copy constructor is a constructor that is and overloaded constructor that copied all of the data from one object and then makes a copy of all those values into another address to be accessed. However, problem can arise from doing this is one is not careful and might develop a self assignment to itself which can be very problematic. This is where deep and shallow copy play a big role in copy constructors. And No you do not need a copy constructor for every class you define. The times that using a copy constructor is mainly when you are wanting to allocated new memory dynamically from the heap. The compiler will automatically copy basic default values without having to use a copy constructor but one, it will move a lot slower and two, with default creating copy constructor for a class using pointers can create a wide ariety of issues. Thus, whenever the user is using new memory, it is best to use the copy constructor, if not, then it is probably best to just not use the copy constructor.



Copy Constructor

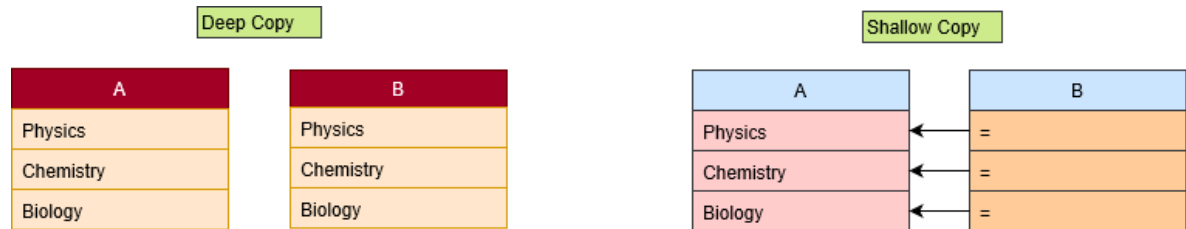
- A copy constructor is called whenever a new variable is created from an object

```
- Point p(5,5);  
- Point a = p; // Copy constructor call!  
- Point b(p); // Copy constructor call!
```
- C++ creates **default copy constructor** automatically

- (d) (5 points) What is a deep copy, and when do you need to worry about it?

A deep copy is a copy that is created when the user wants to copy everything over using a pointer. By this when using pointer types in C++, when the deep copy is made, everything is copied over from the object over to new allocated memory and the pointer will create a new allocated

memory spot that it points to each time a new object is created. The time that this should be used is when you are wanting to allocated new memory for the creation of new objects.



- (e) (5 points) Is there a relationship between copy constructors and deep copying?

Yes there is. The reason for this being the case is if the user wants to create a deep copy of an object, then the constructor will copy everything over from the constructor, assign it new memory and utilize all the contents of the copy constructor. I.e if the user wants to create a deep copy of say a class car object, the deep copy will gather all of that information using the copy constructor and create a new instance and thereby the relationship between the two is instantiated.

- (f) (5 points) Is a copy constructor the same as overloading the assignment operator?

They are not the same. The one thing they do have in common are both are used to initializing one object to another object. The big difference between the two is that the copy constructor creates a separate memory space allocated for the new object. But the assignment operator does not create new space. It instead it uses the reference variable to point to the previous memory block.

Example of assignment operator `classname Obj1,Obj2;`

`Obj2=Obj1;//assigning obj1 to obj2`

Example of copy constructor `classname (const classname & rhs){//`

`//body of copy constructor};`

(g) (10 points) Give one or more reason(s) why a class would need a destructor.

A class would need a destructor if memory is allocated over and over again and a destructor is necessary if memory is allocated to the heap. This in term helps free up borrowed memory is memory is being allocated a lot through the instance of the new key word when creating new instances. This in turns just helps out the memory of the program to run more efficiently. Especially if the constructor is creating a lot of objects and after it is done using the object and doesn't need them anymore, the code will destroy that object and then begin again.

4. (10 points) What is the difference between an abstract class and an interface?

Hint:

You should include in your discussion:

- Virtual Functions
- Pure Virtual Functions

5. An abstract class that is referred to in OOP has at least one abstract method. This method has no code in its base class, instead, the code will be derived from its derived class this method in the derived class must be implemented with the same access modifier, numbers, and type and have the same return type as that of the original base class. The objects of the abstract class type are not created because the code itself is the one that creates the instance of an object from the abstract class would create an error upon runtime of a program. This also pertains to virtual functions when you set a value of one class to say for instance, area equals 0, then you call that method function inside of another function, you can override that virtual function by user defined value to be overridden.

An interface main purpose is to describe the behavior and the overall capabilities of a C++ class without committing anything to any certain implementation to the class itself. These interfaces are then implemented using the abstract classes. These can often be confused with data abstraction. This is not the same thing due to the fact that data abstraction is the concept of keeping the implementation and its details hidden and separate from the data that it is associated with.

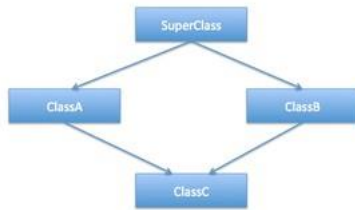
Interface	Abstract class
Interface support multiple inheritance	Abstract class does not support multiple inheritance
Interface does'n Contains Data Member	Abstract class contains Data Member
Interface does'n contains Cunstructors	Abstract class contains Cunstructors
An interface Contains only incomplete member (signature of member)	An abstract class Contains both incomplete (abstract) and complete member
An interface cannot have access modifiers by default everything is assumed as public	An abstract class can contain access modifiers for the subs, functions, properties
Member of interface can not be Static	Only Complete Member of abstract class can be Static

6. Describe the following (make sure you compare and contrast as well):
- (a) (5 points) **Public-** The public keyword is used inside of a class which gives access to any functions or methods contained within with anyone inside of the current program that can be access. These methods contained within this block are then transferred over to the private section within the class that only the public of that class or friends have access to.
 - (b) (5 points) **Private-** The keyword private means that the only one inside of the program that has access to any of the data is those only within the current class or others with the keyword "friend" have access to data within.
 - (c) (5 points) **Protected-** Protected meands that only the current class and the subclassed of that specified class are able to access and of the protected fields or methods, unlike public which can be accessed anywhere throughout the program

Hint:

- Make sure you define each item individually as well.
- Use examples.
- If your not sure, use examples to make your point.
- Ummm, example code is always welcome.

7. (10 points) What is the diamond problem?



Hint:

- This is a question about multiple inheritance and its potential problems.
- Use examples when possible, but explain thoroughly.

The diamond problem is when you have subclass inheriting from multiple parent classes also known as multiple inheritance. The problem arises when the an ambiguity is created from multiple parent classes that the child does not know which method to use or utilize. A solutions to fixing this problem is creating default methods and interfaces. This in turn allows the interfaces to utilizes the same default name with the same default name in two different interfaces to avoid issues with the multiple inheritance. Another solution that has been shown to solve this issue is Virtual inheritance By utilizing virtual inheritance, and ensurity can be made that ensures that the child class gets only a single instance of the common base class. Interestingly enough, I also found out that because of the issues that can arise from this, Java does not support multiple inheritance from more than one class to avoid issues that arise from this.

8. (10 points) Discuss Early and Late binding.

Hint:

- These keywords should be in your answer: **static, dynamic, virtual, abstract, interface**.
- If you haven't figured it out use examples.

When using early binding, the class information is being used to resolve the method calling. This occurs at the compile time. Another name that can be given to early binding is static binding. During the process of Early binding/ static binding, the binding occurs before the compilation and running of the program itself. Methods involving overloading are bonded together when this is implemented.

When using late binding, the object is being used to handle method calling. This method occurs AT RUNTIME. This is often referred to as dynamic binding because upon runtime, the binding of everything together occurs at the runtime. Methods that are overridden (like virtual functions etc) are bonded together using late binding

9. (20 points) Using a **single** variable, execute the show method in *Base* and in *Derived*. Of course you can use other statements as well, but only one variable.

```
class Base{
    public:
    virtual void show() { cout<<" In Base n"; }
};

class Derived: public Base{
    public:
    void show() { cout<<"In Derived n"; }
};
```

Hint: This is implying that dynamic binding should be used. A pointer to the base class can be used to point to the derived as well

```
Derived Obj; //create object from derived class named Obj
Obj.show(); // execute the show method inside of the Derived class
Obj.Base::show(); // execute the show method inside of base class this executes the show method in Base
```

-
- (15 points) Given the two class definitions below:

```
class Engine {} // The Engine class.
class Automobile {}
// Automobile class which is parent to Car class.
```

You need to write a definition for a Car class using the above two classes. You need to extend one, and use the other as a data member. This question boils down to composition vs inheritance. Explain your reasoning after you write your Car definition (bare bones definition).


```
1  class Engine
2  {
3  };
4
5  class Automobiles {
6  };
7
8  //Derived class of the Car
9  class Car :public Automobiles
10 {
11 private:
12     //Member of Car
13     Engine engine;
14 };
15
16 //reasoning
17 // Since car is an automobile, we inherit properties of automobiles
18 // into the class car which has access to the public of auto
19 // this shows inheritance
20
21 // every automobile contains an engine, so since this is the case, in the private section,
22 // the car is composed of all the components making up the car every car has an engine, showing
23 // an example of composition
```

the reasoning I wrote this down the way that I did is described inside of the code that I typed up in notepad plus plus which basically with this example, we are showing inheritance through the car class which has access to the public class of automobiles and it shows composition through accessing the engine class in the private section because all cars have engines.

10. (20 points) Write a class that contains two class data members *numBorn* and *numLiving*. The value of *numBorn* should be equal to the number of objects of the class that have been instantiated. The value of *numLiving* should be equal to the total number of objects in existence currently (i.e., the objects that have been constructed but not yet destroyed.) use static keyword

```

main.cpp
1 #include<iostream>
2 using namespace std;
3 //class called living things
4 class LivingThings
5 {
6 private:
7     //number that born and living
8     int numBorn;
9     int numLiving;
10
11 public:
12     //initialize static variables for
13     //born objects and numliving
14     static int numOfBornObjects;
15     static int numOfLivingObjects;
16     //Constructor for class LivingThings
17     LivingThings()//defaults
18     {
19         numBorn = numOfBornObjects;
20         numLiving = numOfLivingObjects;
21         numOfLivingObjects++ numOfBornObjects++;
22     }
23     //destructor for class
24     ~LivingThings()
25     {
26         //decrementing
27         numOfLivingObjects--;
28     }
29 };
30
31 //global static incremented and decremented
32 int LivingThings::numOfBornObjects = 0;
33 int LivingThings::numOfLivingObjects = 0;
34
35 int main()
36 {
37     //creating objects from the class living things
38     LivingThings obj, obj1, obj2;
39     cout << "Number of Born Objects: " <<
40     obj2.numOfBornObjects << endl;
41     obj2.~LivingThings();//call the destructor of obj2
42     obj2.~LivingThings();//call the destructor of obj2
43     //print out the results of the number of living objects
44     cout << "Number of Living Objects: " <<
45     obj2.numOfLivingObjects << endl;
46     return 0;
47 }
48 //the definition of abstraction in C++ is the creation of a functionality of a created class, but

```

```

Console
> clang++-7 -pthread -std=c++17 -o main main.cpp
> ./main
Number of Born Objects: 3
Number of Living Objects: 1

```

Each time object is created and dies, the number count goes up and the numliving ins incremented and decremented through the class and the calls in main. The number is pronounced static for both which holds value for the numlvng and num dead which once one is destroy in the call in main, then it will utilize the destructor. And increment and then decremet

11. (a) (10 points) Write a program that has an abstract base class named *Quad*. This class should have four member data variables representing side lengths and a *pure virtual function* called *Area*. It should also have methods for setting the data variables.
- (b) (15 points) Derive a class *Rectangle* from *Quad* and override the *Area* method so that it returns the area of the Rectangle. Write a main function that creates a Rectangle and sets the side lengths.
- (c) (10 points) Write a top-level function that will take a parameter of type *Quad* and return the value of the appropriate Area function.

Note: A **top-level function** is a function that is basically stand-alone. This means that they are functions you ca directly, without the need to create any object or call any class.

SHOWN BELOW IN SCREENSHOT

```
1 #include<iostream>
2 using namespace std;
3 class Quad //create class named quad
4 {
5     protected:
6         double height, width;//lengths
7     public:
8         //methods
9         //virtual default to area 0
10        //will be overridden with rect class
11        virtual double Area() = 0;
12        //create a setter for comp area
13        void setSides(double h, double w)
14        {
15            height = h;
16            width = w;
17        }
18 };
19 //below is the rectangle class implementing the quad class
20 //class rectangle has access to public of quad
21 class Rectangle :public Quad
22 {
23     //here we override the area methods
24     public:
25         double Area() //default
26         {
27             return height * width;
28         }
29 };
30
31 double getArea(Quad &quad)
32 {
33     //used in top level function in main
34     return quad.Area();
35 }
36
37 //for testing implement in main
38 int main()
39 {
40     //create obj rect derived from rectangle class
41     Rectangle rect;
42     //set sides
43     rect.setSides(20, 20);
44     //calling the toplevel function
45     cout << "the are of rectangle is: " <<
46     getArea(rect) << endl;
47     return 0;
48 }
```

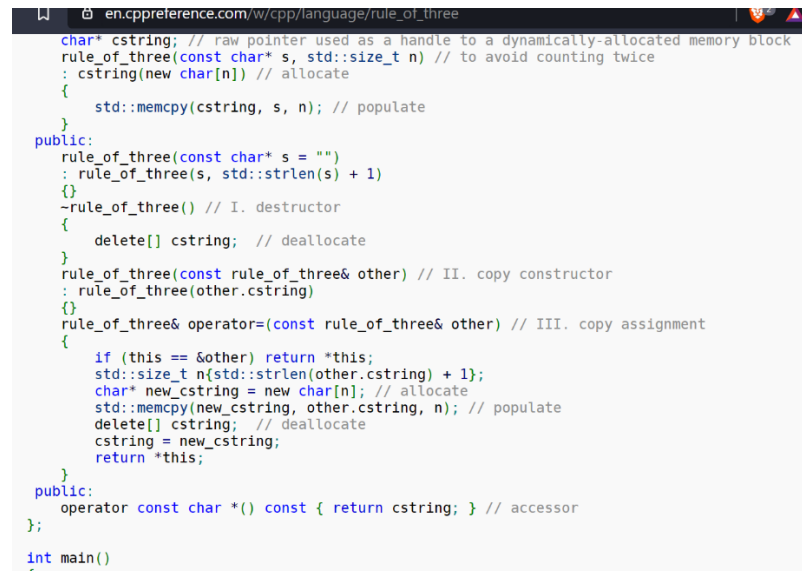
```
> clang++-7 -pthread -std=c++17 -o main main.cpp
> ./main
the are of rectangle is: 400
```

This is wrote, compile and ran in replit, utilized the public keyword to have access to the other class which overrides the virtual=o and changes the value

12. (10 points) What is the rule of three? You will have answered this question (in pieces) already, but in the OOP world, what does it mean?

The rule of three when talking about OOP is if you are using either a destructor, copy constructor, or the copy assignment operator inside of your class, then it is probably best to incorporate all three inside your program.

To understand why this is one must understand what default constructors and the assignment operators do. They create shallow copies and we as the writer create our own constructors and assignment operators whenever we create a deep copy (dynamically create objects with pointers to types). A destructors main job is to run whenever the object is being destroyed. If we were to only affects the contents of the specified object the need for the destructor wouldn't be very pertinent. Thus, the destructor affects the whole program overall when destroying an object. If our class does not have a copy constructor, then whenever the destructor is being called, then it can lead to errors when compiling code because it doesn't allocate memory for the new object it is pointing to so it leads to a program failure. Whenever we do not create a copy assignment operator, The system will implicitly assign data to the sources data members and thus will lead to another compilation crash as well because there is no memory allocated for new object assignments. There is also the rule of five which include the move operator and the move assignment operator as well. I am providing an explicit example below with coded example.



```

char* cstring; // raw pointer used as a handle to a dynamically-allocated memory block
rule_of_three(const char* s, std::size_t n) // to avoid counting twice
: cstring(new char[n]) // allocate
{
    std::memcpy(cstring, s, n); // populate
}
public:
rule_of_three(const char* s = "")
: rule_of_three(s, std::strlen(s) + 1)
{}
~rule_of_three() // I. destructor
{
    delete[] cstring; // deallocate
}
rule_of_three(const rule_of_three& other) // II. copy constructor
: rule_of_three(other.cstring)
{}
rule_of_three& operator=(const rule_of_three& other) // III. copy assignment
{
    if (this == &other) return *this;
    std::size_t n(std::strlen(other.cstring) + 1);
    char* new_cstring = new char[n]; // allocate
    std::memcpy(new_cstring, other.cstring, n); // populate
    delete[] cstring; // deallocate
    cstring = new_cstring;
    return *this;
}
public:
operator const char*() const { return cstring; } // accessor
};

int main()

```

Code cited below

13. (10 points) What are the limitations of OOP?

There are pros and cons of OOP. Some of the pros of oop are a even though some of it may be tedious, implementation of OOP produces better productivity inside of the code itself. While some of the processes of using OOP may be tedious, in the long run it makes coding more efficient when dealing with the creation and implementation of code. It also helps in the cost of project implementation allow other users to easily share with one another.

There is steep learning curve to learning oop especially since OOp deals with objects and the user has the ability to change many aspects of the objects themselves include the assignment, the operators for object as well the as the format of the input and output associated with them in a programs.

Personally, I found a lot of the aspects to be very compounded especially when exploring just how many options were available using object oriented programming that I associated with other coding that I have done outside of class and found it very useful. However, some of the disadvantages of OOP is the fact that because the user has the ability to utilize object formatting techniques inside of the code through various means like inheritance, abstraction, and overloading, programs tend to get longer and run a little bit slower. A advantage to this instance is the fact that because the user is able to implement a plethora of different strategies to compound upon in classes, structures etc, the code itself tends to be more thorough and well written and less "clunky" without it.

Works Cited

Author: note. While I used a lot of sources in the researching of my entire document, attached are the various sources that I used upon compilation and the writing of my entire exam.

“Advantages & Disadvantages of Object-Oriented Programming | Techwalla.com.” *Techwalla*, 2015, www.techwalla.com/articles/advantages-disadvantages-of-object-oriented-programming.

Bain, Author Scott. “Advice from the GoF: Favor Composition over Inheritance.” *Net Objectives Thoughts*, 15 July 2019, netobjectivesthoughts.com/advice-from-the-gof-favor-composition-over-inheritance/. Accessed 29 Apr. 2021.

ballen. “I Finally Understand Static vs. Dynamic Typing and You Will Too!” *Hackernoon.com*, 2017, hackernoon.com/i-finally-understand-static-vs-dynamic-typing-and-you-will-too-ad0c2bd0acc7.

“C++ Overloading (Operator and Function) - Tutorialspoint.” *Www.tutorialspoint.com*, www.tutorialspoint.com/cplusplus/cpp_overloading.htm.

“Copy Constructor vs Assignment Operator in C++.” *Www.tutorialspoint.com*, www.tutorialspoint.com/cplusplus/copy-constructor-vs-assignment-operator-in-cplusplus. Accessed 29 Apr. 2021.

Deep Copy Constructor in C++ – FreshlyBuilt.com. freshlybuilt.com/deep-copy-constructor-in-c/. Accessed 29 Apr. 2021.

“Difference between Method Overloading and Overriding.” *Net-Information.com*, net-informations.com/faq/oops/overloading.htm. Accessed 29 Apr. 2021.

“Difference between Virtual Function and Pure Virtual Function in C++.” *GeeksforGeeks*, 22 Jan. 2020, www.geeksforgeeks.org/difference-between-virtual-function-and-pure-virtual-function-in-c/. Accessed 29 Apr. 2021.

ForGeeks, Geeks. “Polymorphism in C++.” *GeeksforGeeks*, 22 May 2017, www.geeksforgeeks.org/polymorphism-in-c/.

---. "Type Systems:Dynamic Typing, Static Typing & Duck Typing." *GeeksforGeeks*, 17 Mar. 2019, www.geeksforgeeks.org/type-systemsdynamic-typing-static-typing-duck-typing/.

"Inheritance in C++." *GeeksforGeeks*, 25 May 2017, www.geeksforgeeks.org/inheritance-in-c/.

OverFlow(Anon), Stack. "Oop - When Should You Use a Class vs a Struct in C++?" *Stack Overflow*, stackoverflow.com/questions/54585/when-should-you-use-a-class-vs-a-struct-in-c. Accessed 29 Apr. 2021.

"Overloading the Copy Constructor and the Assignment Operator." *Icarus.cs.weber.edu*, icarus.cs.weber.edu/~dab/cs1410/textbook/14.CPP_Relationships/copying.html. Accessed 29 Apr. 2021.

"Rule of Three in C++." *GeeksforGeeks*, 18 Aug. 2017, www.geeksforgeeks.org/rule-of-three-in-cpp/. Accessed 29 Apr. 2021.

sirama. "Deep Copy and Shallow Copy in C++ with Example." *Owlcation*, owlcation.com/stem/Copy-Constructor-shallow-copy-vs-deep-copy. Accessed 29 Apr. 2021.

"What Is the Difference between Early and Late Binding?" *Stack Overflow*, stackoverflow.com/questions/10580/what-is-the-difference-between-early-and-late-binding. Accessed 25 Apr. 2021.

Technolush.com, 2021, www.technolush.com/uploads/2020-01-20/banner/technolush-interface-vs-abstract-class-php-banner.jpg. Accessed 29 Apr. 2021.

"The Rule of Three/Five/Zero - Cppreference.com." *En.cppreference.com*, en.cppreference.com/w/cpp/language/rule_of_three. Accessed 25 Apr. 2021.