1. Write the number of the definition on the right next to the term it defines.

(a) **class** 3

(b) **constructor** 4

(c) **container** 12

(d) **copy** 1

(e) **invariant** 10

(f) **overload** 7

(g) **reference** 6

(h) **pointer** 5

(i) **scope** 2

(j) **byte** 11

(k) **type** 9

(l) **move** 8

(1) An operation that makes two objects have values that compare equal..

(2) The region of program text (source code) in which a name can be referred to.

(3) A user-defined type that may contain data members, function members, and member types.

(4) An operation that initializes an object. Typically establishes an invariant and often acquires resources needed for an object to be used (which are then typically released by a destructor).

(5) (1) a value used to identify a typed object in memory; (2) a variable holding such a value.

(6) (1) a value describing the location of a typed value in memory; (2) a variable holding such a value.

(7) Define two functions or operators with the same name but different argument (operand) types.

(8) an operation that transfers a value from one object to another, leaving behind a value representing "empty."

(9) Something that defines a set of possible values and a set of operations for an object.

(10) Something that must be always true at a given point (or points) of a program; typically used to describe the state (set of values) of an object or the state of a loop before entry into the repeated statement.

(11) The basic unit of addressing in most computers.

(12) An object that holds elements (other objects).

2. Consider the following code fragment for the user-defined type, `Token`:

```
1 struct Token{
      char kind;
3     double value;
      string varname;
5     Token(char ch) :kind(ch), value(0) { }
      Token(char ch, double val) :kind(ch), value(val) { }
7     Token(char ch, string val) :kind(ch), varname(val) { }
};
```

(a) What `kind` values are used to declare a variable?
ANS: A variable is created with the **Token(name,s)** constructor, where `name` is a `const char` set to `'a'` and `s` is the `string`. Also, the program officially declares a variable with this member function of the `Symbol_table` class:

```
void declare(string s, double d, bool b)
2{   for (int i = 0; i<int(names.size()); ++i)
         if (names[i].name == s) error("declare: existing name ",s);
4    names.push_back(Variable(s,d,b));
}
```

The function searches through the existing variable names and, if it finds `s` among them, throws an error, otherwise it dutifully constructs a new variable name `s` with its value `d` and bool `b` to determine whether its a constant or not, and pushes this onto the `symbol_table`'s vector, `names` or `Variables`.

(b) Describe in detail the ways in which the constructors for `Token` are used.
ANS: In addition to the rather complex construction of a variable token described above, an operator token is constructed with `Token(ch)` where `ch` is a variable of type `char` and represents an operation like `'+'`, or a keyword for a function operator like `let` (`let = 'L'`) `constant` (`constant = 'C'`), `sqrt` (`sqrt = 'S'`) and so on. The `value` of an operator token is given the default value = 0 and the `varname` for an operator token is just ignored (the empty string). A number token is constructed with `Token(number,val)` where `number` is the `const char, '8'` and `val` is a variable of type `double`, the value of the number token.

(c) Describe how to change `Token` from a `struct` to a `class`.
ANS: Consider it done (note the use of the word `public`. The default setting for a `class` is `private`. We could make the data members private, but then accessors would likely be needed:

3. Consider the following code fragment for the user-defined type, `Token_stream`

```
1 struct Token_stream {
      bool full;
3     Token buffer;
      istream & str;
5     Token_stream(istream & arg) : str(arg), full(0), buffer('␣') { }
      Token get();
7     void unget(Token t) { buffer=t; full=true; }
      void ignore(char);
9 };
```

(a) Describe the variable `buffer`. What is it? What is it for? Give an example of how it is used.
ANS: The `token_stream buffer` is one of two (or three) member variables of the `Token_stream` class. It is a variable of type `Token` and is for holding a Token that can't be processed immediately. For instance, if the `term()` function's call to `get()` (`Token t = str.get()`) gets a `(+,0,"")` token, then that token goes into the `Token_stream buffer` and control passes back to `expression()` which will get the next term before retrieving the plus token from the buffer and doing the addition of terms. There are a variety of other circumstances where the `Token_stream buffer` is used.

(b) Describe the variable `str`. What is it? What is it for? Give an example of how it is used.
ANS: The variable `str` is a variable of type `istream&` (a reference to an `istream`). It is a third member variable of the class `Token_stream` that was added to make streaming sources more flexible. For instance, we could create from the start (in `main()`), an input file stream and assign it to an `istream` like so:

```
ifstream fs("inExpr.txt");
istream& istrm = fs;
```

and then construct `Token_stream ts`, and pass that by reference each time one function calls another that needs it. Since this is a member variable of `Token_stream ts`, `istrm` gets passed along with `ts`. If it's pointing to a file `inExpr.txt` that contains, say, `"5 + 12;"` then `main()` calls `calculate(ts)`, which calls `statement(ts)` by printing its output to the console (and/or to a file?), then `expression(ts)` is called and its output is assigned to a variable `left` of type `double`, to be returned to `statement()`, and `expression()` then gets the term 5 by calling `primary(ts)` through `term(ts)` and adds to that to the term (stored in the `double left`), replacing `left` now with the sum, 17, at which point `expression()` encounters the token `(';',0,"")`, which it puts in the `Token_stream buffer` with `ts.unget(t)` (aka `put_back()`, then `left=17` is returned to `statement()` which recovers the print token from the buffer and returns 17 to `calculate()`, printing it to the console and looking (with `while(ts.str)`) to see if there's more input or not. If we're at the end of the file (`eof`), then that's all folks, otherwise we start again.

4. Consider the following code fragment for the member function `get()`.

```
1  Token Token_stream::get() {
       if (full) { full=false; return buffer; }
3      char ch;
       str >> ch;
5      if (! str) return(Token(quit));
       switch (ch) {
7      case '(':   case ')':       case '+':       case '-':       case '*':
       case '/':   case '%':       case ';':       case '=':       case ',':
9          return Token(ch);
       case '.':   case '0':       case '1':       case '2':       case '3':
11     case '4':   case '5':       case '6':       case '7':       case '8':
       case '9':
13     {   str.unget();
           double val;
15         str >> val;
           if (! str) error("Bad␣token");
17         return Token(number,val);
       }
19     default:
           if (isalpha(ch) || ch == '_') {
21             string s; s += ch;
               while(str.get(ch) &&
23                   (isalpha(ch) || isdigit(ch) || ch == '_'))
                   s += ch;
25             str.unget();
               if (! str) error("Bad␣token");
27             if (s == "let") return Token(let);
               if (s == "const") return Token(constant);
29             if (s == "reset") return Token(reset);
               if (s == "sqrt") return Token(sqroot);
31             if (s == "pow") return Token(power);
               if (s == "help") return Token(help);
33             if (s == "quit" || s == "exit")
                   return Token(quit);
35             return Token(name,s);
           }
37         error("Bad␣token");
           return Token('␣');
39     }
   }
```

(a) What does `get()` get if `full==true`?
ANS: Whatever token is stored in `buffer`.

(b) What is `str` here?
ANS: It's none other than the reference to an `istream` which is a member variable of `Token_stream`–after all, we are in the scope of `Token_stream` here.

(c) What is the purpose of `str.unget()` on line 14?
ANS: If you encountered a character that could be the first character of a double, put it back with `unget()` (this is the consoles `unget()`, not `Token_stream's`) and then use the `istream& str` to get the whole `double` in one go.

(d) Describe what happens in the `default case`. How does it provide for the declaration of a new variable? How does handle a built-in function like `pow()`? How does it recognize an existing variable in

symbol_table?
ANS: You get to the default case if buffer is empty the character get() gets is not a simple arithmetic operator or a number token. In that case we check to see if the next character is either alphabetic or "_", in which case we start a string s with it and keep concatenating to s while characters are alphabetic, digit or "_". As soon as we get something other than those things we put it back in the istream buffer and check whether s== to one of the "special" operator token types like let, const, sqrt, pow, or quit, in which cases we construct the appropriate special operator token and return it...otherwise it's a variable token, so we construct a variable token and return that.

5. Rewrite the calculator program to incorporate the variable
```
istream& str;
```
as a member variable of Token_stream, rather than passing it from function to function by reference. Email your complete working code to ghagopian@collegeofthedesert.edu.

6. Consider the following code fragment for handling Variables in the calculator.

```
struct Variable {
    string name;
    double value;
    bool immutable;
    Variable(string n, double v, bool b) :
        name(n), value(v), immutable(b) { }
};

//  The active variables.
class Symbol_table {
    vector<Variable> names;
public:

double get(string s) {
    for (int i = 0; i<int(names.size()); ++i)
        if (names[i].name == s) return names[i].value;
    error("get: undefined name ",s);
        return 0.0;
}

void set(string s, double d)
{   for (int i = 0; i<=int(names.size()); ++i)
        if (names[i].name == s) {
            names[i].value = d;
            return;
        }
    error("set: undefined name ",s);
}
```

(a) Describe the constructor for a Variable. How does it work?
ANS: Variable(string n, double v , bool b) uses the initiation list to set the values of the member variables name, value, and immutable. Notably, Variable is global.

(b) What is Symbol_table. What purpose does it serve?
ANS: The class Symbol_table has a private data member which is vector<Variable> names and contains all the variables that have been declared using the let token and the declaration() function. There are member functions get() and set() and declare() for keeping track of new and old variables and their values.

(c) Why does this `get()` function not collide with `Token_stream`'s `get()` function?
ANS: They have different scopes. One is a member of the `Symbol_table` class and the other is a member of the `Token_stream` class.

(d) Describe in detail how `get()` works and what its purpose is.
ANS: This get is called when `primary()` encounters a `name` token. It takes a string as an argument and searches through the vector or `Variable`s, `names`, for that string. If it finds the string in `names` it returns its value with `names[i].value` to `primary()`, if it doesn't find it it throws an `error("get: undefined name ", s)`.

(e) Describe in detail how `set()` works and what its purpose is.
ANS: `Symbol_table`'s `set()` function is called by the `declaration()` function and takes two parameters: `string s` and `double d`, then searches through the `names` vector for the `Variable` with name `s`. If it finds `s` it sets the value of that `Variable` with `d` and returns. If it doesn't find `s` in `names` it throws an error with the message "set: undefined name ".

(f) Could these `get()` and `set()` functions be made member functions of the `struct Variable`? Discuss.
ANS: Yes, but that would be a less clear way to handle these functions, since it's `Symbol_table`'s job to manage `Variable`s.