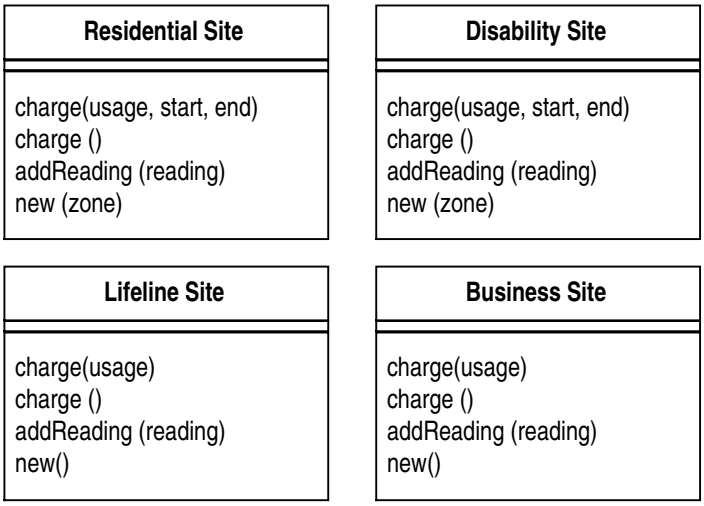
Refactoring and Inheritance

Inheritance is one of the most famous features of object-oriented systems, and so it should come as no surprise that refactoring is a good way to help make the best use of inheritance. To demonstrate some refactoring techniques with inheritance I am going to work with a bunch of classes that form a classic inhertance structure. The example problem is that of an electricity utility charging its customers. The utility has several kinds of customers and charges them in different ways. In all cases, however, it wants to know how many dollars it should charge them for the latest reading.

The types of customer are: Resdidential, Disability, Lifeline, and Business.



In each case the principal task of the class is to calculate the latest charge. The algorithms show quite different code but, as we shall see, there is still a great deal of commonality.

To begin with, however, we shall look at the code. I shall start with the Residential Site class.

```
class ResidentialSite extends DomainObject {


   private Reading[] _readings = new Reading[1000];
   private static final double TAX_RATE = 0.05;
   private Zone _zone;

   ResidentialSite (Zone zone) {
      _zone = zone;
    }
```

Readings are added to the residential site with

```
   public void addReading(Reading newReading)
      {
      // add reading to end of array
      int i = 0;
      while (_readings[i] != null) i++;
      _readings[i] = newReading;
      }
```

Like all the site classes there is a public charge method which calculates the latest charge for the site.

```
   public Dollars charge()
      {
      // find last reading
      int i = 0;
      while (_readings[i] != null) i++;

      int usage = _readings[i-1].amount() - _readings[i-2].amount();
```

```
    Date end = _readings[i-1].date();
    Date start = _readings[i-2].date();
    start.setDate(start.getDate() + 1);    //set to begining of period
    return charge(usage, start, end);
   }
```

As you can see, all it does is set up the arguments for another charge method, which is private to the class.

```
  private Dollars charge(int usage, Date start, Date end) {

    Dollars result;
    double summerFraction;

    // Find out how much of period is in the summer
    if (start.after(_zone.summerEnd()) || end.before(_zone.summerStart()))
       summerFraction = 0;
    else if (!start.before(_zone.summerStart()) && !start.after(_zone.summerEnd()) &&
          !end.before(_zone.summerStart()) && !end.after(_zone.summerEnd()))
       summerFraction = 1;
    else { // part in summer part in winter
       double summerDays;
       if (start.before(_zone.summerStart()) || start.after(_zone.summerEnd())) {
         // end is in the summer
         summerDays = dayOfYear(end) - dayOfYear (_zone.summerStart()) + 1;
       } else {
         // start is in summer
         summerDays = dayOfYear(_zone.summerEnd()) - dayOfYear (start) + 1;
       };
       summerFraction = summerDays / (dayOfYear(end) - dayOfYear(start) + 1);
    };

    result =  new Dollars ((usage * _zone.summerRate() * summerFraction) +
       (usage * _zone.winterRate() * (1 - summerFraction)));


    result = result.plus(new Dollars (result.times(TAX_RATE)));

    Dollars fuel = new Dollars(usage * 0.0175);
    result = result.plus(fuel);

    result = new Dollars (result.plus(fuel.times(TAX_RATE)));

    return result;

   }
```

This is a complicated beast. It makes use of one further method to help with date calculations.

```
    int dayOfYear(Date arg) {
    int result;
    switch (arg.getMonth()) {
       case 0:
         result = 0;
         break;
       case 1:
         result = 31;
         break;
       case 2:
         result = 59;
         break;
       case 3:
         result = 90;
         break;
       case 4:
         result = 120;
         break;
       case 5:
         result = 151;
         break;
       case 6:
         result = 181;
         break;
       case 7:
         result = 212;
         break;
       case 8:
         result = 243;
         break;
       case 9:
         result = 273;
         break;
```

```
        case 10:
          result = 304;
          break;
        case 11:
          result = 334;
          break;
        default :
          throw new IllegalArgumentException();
    };
    result += arg.getDate();

    //check leap year
    if ((arg.getYear()%4 == 0) && ((arg.getYear() % 100 != 0) || (arg.getYear() % 400 ==
0))) {
        result++;
    };

    return result;
    }
```

That (at least for our purposes) is the residential site class. The residential site uses a number of other classes. The readsings and zone classes are just simple encapsualted records.

```
class Reading {
    public Date date() {
        return _date;
    }
    public int amount() {
        return _amount;
    }
    public Reading(int amount, Date date) {
        _amount = amount;
        _date = date;
    }

    private Date _date;
    private int _amount;
}

class Zone {
  public Zone persist()      {
     Registrar.add("Zone", this);
     return this;
  }

  public static Zone get (String name)      {
     return (Zone) Registrar.get("Zone", name);
  }

  public Date summerEnd() {
     return _summerEnd;
  }

  public Date summerStart() {
     return _summerStart;
  }

  public double winterRate() {
     return _winterRate;
  }

  public double summerRate() {
     return _summerRate;
  }


  Zone (String name, double summerRate, double winterRate,
                Date summerStart, Date summerEnd) {
     _name = name;
     _summerRate = summerRate;
     _winterRate = winterRate;
     _summerStart = summerStart;
     _summerEnd = summerEnd;
  };

  private Date _summerEnd;
  private Date _summerStart;
  private double _winterRate;
  private double _summerRate;
  }
```

The dollars class is a use of the Quantity pattern. It combines the notion of an amount and a currency. I'm not going to go into too many details here. Essentially you create dollars objects with a constructor that has a number for the amount. The class supports some basic arithmetic operations.

An important part of the dollars class is the fact that it rounds all numbers to the nearest cent, a behavior which is often very important in financial systems. As my friend Ron Jeffries told me: "Be kind to pennies, and they will be kind to you".

Next up is a class used for calculating charges for people who are disabled. Its structure is similar to the residential case except for a few more constants.

```
class DisabilitySite {
     private Reading[] _readings = new Reading[1000];
     private static final Dollars FUEL_TAX_CAP = new Dollars (0.10);
     private static final double TAX_RATE = 0.05;
     private Zone _zone;
     private static final int CAP = 200;
```

Again it has a method for adding new readings

```
public void addReading(Reading newReading)
     {
     int i;
     for (i = 0; _readings[i] != null; i++);
     _readings[i] = newReading;
     }
```

There are also two charge methods. The first is public and takes no arguments.

```
public Dollars charge()
     {
     int i;
     for (i = 0; _readings[i] != null; i++);

     int usage = _readings[i-1].amount() - _readings[i-2].amount();
     Date end = _readings[i-1].date();
     Date start = _readings[i-2].date();
     start.setDate(start.getDate() + 1);    //set to begining of period
     return charge(usage, start, end);
     }
```

The second is the private, three argument method.

```
private Dollars charge(int fullUsage, Date start, Date end) {
     Dollars result;
     double summerFraction;
     int usage = Math.min(fullUsage, CAP);

     if (start.after(_zone.summerEnd()) || end.before(_zone.summerStart()))
        summerFraction = 0;
     else if (!start.before(_zone.summerStart()) && !start.after(_zone.summerEnd()) &&
            !end.before(_zone.summerStart()) && !end.after(_zone.summerEnd()))
        summerFraction = 1;
     else {
        double summerDays;
        if (start.before(_zone.summerStart()) || start.after(_zone.summerEnd())) {
          // end is in the summer
          summerDays = dayOfYear(end) - dayOfYear (_zone.summerStart()) + 1;
        } else {
          // start is in summer
          summerDays = dayOfYear(_zone.summerEnd()) - dayOfYear (start) + 1;
        };
        summerFraction = summerDays / (dayOfYear(end) - dayOfYear(start) + 1);
     };

     result =  new Dollars ((usage * _zone.summerRate() * summerFraction) +
        (usage * _zone.winterRate() * (1 - summerFraction)));

     result = result.plus(new Dollars (Math.max(fullUsage - usage, 0) * 0.062));


     result = result.plus(new Dollars (result.times(TAX_RATE)));

     Dollars fuel = new Dollars(fullUsage * 0.0175);
     result = result.plus(fuel);
     result = new Dollars (result.plus(fuel.times(TAX_RATE).min(FUEL_TAX_CAP)));
```

```
    return result;
  }
```

This again uses a dayOfYear method which is identical to the one for the residential site.

Our next site is called a lifeline site, used for people who claim special state dispensation due to poverty.

```
public class LifelineSite extends DomainObject {

  private Reading[] _readings = new Reading[1000];
  private static final double TAX_RATE = 0.05;
```

The method to add a reading looks different this time

```
public void addReading(Reading newReading) {
    Reading[] newArray = new Reading[_readings.length + 1];
    System.arraycopy(_readings, 0, newArray, 1, _readings.length);
    newArray[0] = newReading;
    _readings = newArray;
}
```

Again there is a charge method with no parameters.

```
public Dollars charge()
    {
    int usage = _readings[0].amount() - _readings[1].amount();
    return charge(usage);
    }
```

But this time the private charge method only takes one parameter

```
  private Dollars charge  (int usage) {

    double base = Math.min(usage,100) * 0.03;
    if (usage > 100) {
       base += (Math.min (usage,200) - 100) * 0.05;
    };
    if (usage > 200) {
       base += (usage - 200) * 0.07;
    };

    Dollars result = new Dollars (base);

    Dollars tax = new Dollars (
           result.minus(new Dollars(8)).max(new Dollars (0)).times(TAX_RATE)
    );
    result = result.plus(tax);

    Dollars fuelCharge = new Dollars (usage * 0.0175);
    result = result.plus (fuelCharge);
    return result.plus (new Dollars (fuelCharge.times(TAX_RATE)));
  }
```

Our last site is the business site

```
class BusinessSite {
  private int lastReading;
  private Reading[] _readings = new Reading[1000];
  private static final double START_RATE = 0.09;
  static final double END_RATE = 0.05;
  static final int END_AMOUNT = 1000;
```

There is another variation for adding a reading

```
public void addReading(Reading newReading) {
    _readings[++lastReading] = newReading;
}
private int lastReading;
```

Again there is a no-argument charge method

```
public Dollars charge()
    {
    int usage = _readings[lastReading].amount() - _readings[lastReading -1].amount();
    return charge(usage);
    }
```

And a one-argument charge method.

```
private  Dollars charge(int usage) {
    Dollars result;

   if (usage == 0) return new Dollars(0);

  double t1 = START_RATE - ((END_RATE * END_AMOUNT) - START_RATE) / (END_AMOUNT - 1);
  double t2 = ((END_RATE * END_AMOUNT) - START_RATE) * Math.min(END_AMOUNT, usage) /
                                          (END_AMOUNT - 1);
  double t3 = Math.max(usage - END_AMOUNT, 0) * END_RATE;

  result = new Dollars (t1 + t2 + t3);

  result = result.plus(new Dollars (usage * 0.0175));

  Dollars base = new Dollars (result.min(new Dollars (50)).times(0.07));
     if (result.isGreaterThan(new Dollars (50))) {
        base = new Dollars (base.plus(result.min(new Dollars(75)).minus(
          new Dollars(50)).times(0.06)
        ));
     };
     if (result.isGreaterThan(new Dollars (75))) {
        base = new Dollars (base.plus(result.minus(new Dollars(75)).times(0.05)));
     };
  result = result.plus(base);
  return result;

    }
```

First step in refactoring

The first step in refactoring is to set up a good set of tests so that we can be sure that the external behavior does not change.

Increasingly you can get some nice testing tools to go with Java., and if you are doing any serious application development you should buy this kind of testing tool. But when I was writing this chapter I didn't have access to any of these tools, so I rolled a simple testing framework of my own. It's not the kind of thing I would expect in a serious project, so I'm kind of embarassed to show it. But it does illustrate some important principles and anyone can easily use it (yes that does include you).

The essence of the framework is the Tester and TestResult classes. The Tester class is a simple abstract class that provices basic services for executing tests.

```
Class Tester {

  void executeTest() {
     try {
        test();
        System.out.println (_result);
      } catch (Exception e) {
          System.out.println ("Exception while executing: " + e.toString());
          e.printStackTrace(System.out);
      };
  }


  protected void addFailure (String message) {
      _result.addFailure(message);
  }


  abstract void test() throws Exception;
```

A subclass of tester must provide a main method and implement test().

```
Class SiteTester {

  public static void main (String[] argv) {
     new SiteTester().executeTest();
  }

   public void test() throws Exception {
```

```
    setup();
    testLifeline();
    testResidentialB();
    testResidentialC();
    testDisability1();
    testDisability2();
    testBusiness();
    testResidentialA();
  }
```

I keep these classes separate so I can reuse Tester between projects.

The individual methods in SiteTester are along the following lines

```
   void testBusiness() throws Exception{
    BusinessSite subject = new BusinessSite();
    subject.addReading(new Reading (0, new Date ("31 Dec 1996")));
    subject.addReading(new Reading (0, new Date ("1 Jan 1997")));
    shouldEqual ("0", new Dollars(0), subject.charge());
    subject.addReading(new Reading (1, new Date ("1 Feb 1997")));
    shouldEqual ("1", new Dollars(0.12), subject.charge());
    subject.addReading(new Reading (1001, new Date ("1 Mar 1997")));
    shouldEqual ("1000", new Dollars(72.05), subject.charge());
    subject.addReading(new Reading (3001, new Date ("1 Apr 1997")));
    shouldEqual ("2000", new Dollars(143), subject.charge());
  }
```

The basic idea is to create a site, toss in a few readings, check the resuling charge, toss in some more reasings, test the charge again, and so on.

The shouldEqual() method is one I can use in several places, so I define it on tester.

```
  protected void shouldEqual(String message, Quantity expected, Quantity actual) {
    incrementTests();

    if (actual == null) {
      addFailure (message + " should be " + expected.toString() + " was null");
      return;
    };
    if (expected.notEquals(actual)) {
      addFailure (message + " should be " + expected.toString() + " was " +
actual.toString());
    };
  }
```

I prepared similar shouldEqual methods for int and Date.

The testResult class keeps track of the results of the test and can do a simple print of the results.

```
public class TestResult {
   void incrementTests() {
    _numberOfTests ++;
    }

  public TestResult ()       {};

  public void addFailure (String message) {
    _failures.addElement (message);
  };

  public boolean isFailure() {
    return ! _failures.isEmpty();
  };

  public String failureString() {
    String result = "";
    Enumeration e = _failures.elements();
    while (e.hasMoreElements()) {
      result += "\t" + e.nextElement() + "\n";
    };
    return result;
  };



  public String toString()   {
    if (isFailure())
      return "Failures\n" + failureString();
```

```
        else
            return "OK (" + String.valueOf(_numberOfTests) + " tests)";
    }
;

    private int _numberOfTests = 0;
    private Vector _failures = new Vector();
}
```

With this in place I can write a subclass of Tester to do some tests, and execute those tests. The test result will either tell me all is well, or it will tell me how many (and which) tests have failed. I can execute the tests from the command line without needing to use a GUI, or I can run them in the debugger. At the time I wrote this chapter the Café debugger was, to put politely, fragile; so I usually ran things in the command line.

Beginning with ResidentialSite and DisabilitySite

I have no idea which two classes to start with in this case, so I will pick two at random. Well maybe not entirely at random, these two classes do have two fields in common, readings and zone, so there is perhaps a bit more common ground here. Usually I do like to start with those that have the most data in common. But I don't think it matters in this case.

The zone field is really very similar. Each class has a field of type Zone that is set in the constructor. At this point I want to know how the zone is used. To do this I do a find for "_zone" in both files and look to see where it used. As I do this I can see that the zone is not modified after the constructor has set it up, and it used quite a lot in the charge method.

From this I feel ready to create a superclass Site and to move the zone field to it. The first step is to declare the new superclass.

```
class Site {

    Site (Zone zone) {
    _zone = zone;
    }

    protected Zone _zone;
}
```

I then remove the zone field from ResidentialSite and make Site the superclass of ResidentialSite.

```
class ResidentialSite extends Site {

  public ResidentialSite (Zone zone) {
     super (zone);
  };
```

Once I've tested it to make sure everything is all right, I do the same for DisabilitySite.

```
class DisabilitySite extends Site {

  public DisabilitySite (Zone zone) {
     super (zone);
  }
```

By making the zone field protected I can ensure that the subclasses can still work with it as before. Some people feel strongly that fields should not be protected, rather they should be private. If you feel like this you can self encapsulate the zone field at this point and provide a *Getting Method* for it. I'm not so concerned and so I'll leave it protected, at least for the moment.

The next field to move is the readings field. Again I do a find to look at how it is used in the two classes. In both cases it is initialized to a 1000 element array. The addReading method finds the last reading in the array and adds a reading to the end. The charge() method pulls some readings out of the array. I can begin safely by moving the field to Site changing its access to protected.

```
class Site {

    Site (Zone zone) {
    _zone = zone;
```

```
    }

    protected Zone _zone;
    protected Reading[] _readings = new Reading[1000];
```

I then remove it from the subclasses and test.

While the zone field did not have much behavior to deal with, the readings field does, and this seems a reasonable next target for my attention. Although one uses a for loop, and the other a while loop, they both add the new reading to the next null spot in the array. I can therefore pick one of them to move to site, and get rid of both of them.

```
class Site {

  public void addReading(Reading newReading) {
     int i = 0;
     while (_readings[i] != null) i++;
     _readings[i] = newReading;
  }
```

That worked fine, but I don't find the addReading method clearly indicates what it is doing. It is finding the first non null index in the array, and adding the new reading at that point. I would like the code to say that more clearly. I can do that by creating an *Intention Revealing Method* for finding the first unused index in the readings array.

```
class Site {

  public void addReading(Reading newReading) {
     _readings[firstUnusedReadingsIndex()] = newReading;
  }

  private int firstUnusedReadingsIndex () {
     int i = 0;
     while (_readings[i] != null) i++;
     return i;
  }
```

I'm not completely happy about the name "firstUnusedReadingsIndex" but the way the method works seems clearer now.

While I'm looking at the use of the readings field the public charge method seems a good next item to work on. It looks identical in the two classes (I guess it was cut and pasted between them). So I can move it to site.

```
class Site {

  public Dollars charge() {
     // find last reading
     int i = 0;
     while (_readings[i] != null) i++;

     int usage = _readings[i-1].amount() - _readings[i-2].amount();
     Date end = _readings[i-1].date();
     Date start = _readings[i-2].date();
     start.setDate(start.getDate() + 1);    //set to begining of period
     return charge(usage, start, end);
  }
```

The highlighted line above causes a problem because it calls a method that is only defined by the subclasses. To get this to work I need to define an abstract method for charge (int, Date, Date) and loosened the access control on charge (int, Date, Date) to protected so that it can be overridden.

```
abstract class Site {

  public Dollars charge() {
     // find last reading
     int i = 0;
     while (_readings[i] != null) i++;

     int usage = _readings[i-1].amount() - _readings[i-2].amount();
     Date end = _readings[i-1].date();
     Date start = _readings[i-2].date();
     start.setDate(start.getDate() + 1);    //set to begining of period
     return charge(usage, start, end);
  }
```

```
    abstract protected Dollars charge(int fullUsage, Date start, Date end);
}
```

The access control has to be loosened on the subclasses too. I've left the variable names in the abstract method declaration even though they are not necessary since I think they help communicate the use of the method. Since I now have an abstract method the class is abstract, as it should be.

Looking at the method, I can see that the much of the action lies in working with the i-1 and i-2 readings. These are the last reading in the readings array, and the next to last reading. This can be made much clearer. I can start by defining a method to get me the last reading.

```
    private Reading lastReading() {
        return _readings[firstUnusedReadingsIndex() - 1];
    };
```

This allows me to modify charge to:

```
public Dollars charge() {
    // find last reading
    int i = 0;
    while (_readings[i] != null) i++;

    int usage = lastReading().amount() - _readings[i-2].amount();
    Date end = lastReading().date();
    Date start = _readings[i-2].date();
    start.setDate(start.getDate() + 1);    //set to begining of period
    return charge(usage, start, end);
   }
```

I can do the same for the previous reading.

```
    public Dollars charge() {
        int usage = lastReading().amount() - previousReading().amount();
        Date end = lastReading().date();
        Date start = previousReading().date();
        start.setDate(start.getDate() + 1);    //set to begining of period
        return charge(usage, start, end);
    }

    private Reading previousReading() {
        return _readings[firstUnusedReadingsIndex() - 2];
    }
```

The code is now much easier to read. However it will now run slower, because every call to lastReading or previousReading will cause the array to be traversed through the loop in firstUnusedReadingIndex. Since I'm currently refactoring I choose to ignore that. I can easily fix it with an optimization later if it becomes important (I can easily cache the firstUnusedReadingsIndex in a field). During refactoring I don't try to think about optimization, I think only about how easy the program is to understand. I do optimization as a separate stage, driven by profiling tools. I've always found that optimization is much easier to do with well factored code.

While I'm on this method there is a couple of other things I will do. I can make the usage calculation into its own method.

```
    public Dollars charge() {
        Date end = lastReading().date();
        Date start = previousReading().date();
        start.setDate(start.getDate() + 1);    //set to begining of period
        return charge(lastUsage(), start, end);
    }

    private int lastUsage() {
        return lastReading().amount() - previousReading().amount();
    };
```

Since how the end is calculated is pretty clear, I could also remove its temp. I'm not sure whether its not clearer, however, to leave it there to indicate the role it is playing the method call. If I was in Smalltalk I would probably remove it because Smalltalk has keywords for its parameters, which communicate the role of each item in the method call. Java has positional parameters, so I find I'm more inclined to use a temp to show the role of the parameter. In the end these choices come down to what you and your colleagues find the easiest to understand.

Fixing the Start Date

I would like to do something about the start date. Ideally I would like a statement like `start = previousReading().date()++`, but that isn't legal Java. An alternative would be to do something like `start = previousReading().date().nextDay()`, but there is no method along those lines in the class library. I'm treating the Java class library as a given, something I cannot refactor. My next step is to create a *Foreign Method*, a method that should be on Date, but instead I put it in my own class. Then I can write `start = nextDay (previousReading().date())`.

The way I would normally come up with a next day is to return a new date object which is one day later. But this is not quite the same as what the current code does:

```
Date start = previousReading().date();
   start.setDate(start.getDate() + 1);    //set to begining of period
```

The setDate method actually changes the day of the current date. To me this as a very odd thing to do. I think of dates of values, things much like integers and reals. Such things are immutable, there is no notion of altering the number 3 to be some other value, instead you alter the variable to point to a different number. This is different to people. If a person has a name and you change her name, she is still the same person. There is nothing you can change about a number in that way. Quantity is like that too, there is nothing you can change about the quantity $3. Thus in any implementation of Quantity I make the amount and the unit immutable: I set them in the constructor and provide no way of changing them. Date is not like that, it has all these set methods, yet I think of Date as like Quantity and thus it should not be changed.

The problem with allowing values to have mutable data is that it leads to odd bugs. If you say:

```
x = new Quantity (3,"USD");
y = x;
```

you don't expect anything that you can do to y to change x. But with a date that is not true. I can go:

```
x = new Date ("1 Jan 97");
y = x;
y.setDate(2);
```

and x will change as well.

This has actually happened in the program I am refactoring. The tests check that the value returned by charge() is correct for the various cases. There is a side effect of this process, a changing of the dates in the readings. The tests did not catch this.

One of the reasons the tests did not catch this is because the #$%^@ who wrote the tests forgot a useful testing rule. When you test a query method, try testing it a few times in row. If the tester had done that, he would have found the error because subsequent invocations of charge() would have returned a different value. (Authors are supposed to be omniscient, so I won't tell you who wrote the tests.)

This yields a couple of further points. One is, of course, that tests don't catch everything and your security in refactoring (as in any development) is only as good as your tests. But it is no good bleating on about how tests don't guarantee correctness, tests are still your best weapon, and you can incrementally improve tests as you go on. The second point is that refactoring can help you find errors, as you spot odd little things like that, much as code inspection does. Indeed refactoring is rather like an active code inspection.

When I spot a bug like that I immediately update the tests so that they catch this problem, and any obvious similar problems. A repeated call to charge() does that nicely.

The next decision is to how to deal with it. Well I still need come up with a nextDay method. I would like to do it by copying a date and adding one to the new date with setDate, but Date is not cloneable, so I can't copy it with clone. I can easily get around that by using an appropriate constructor.

```
public Dollars charge() {
   Date end = lastReading().date();
   Date start = nextDay(previousReading().date());
   return charge(lastUsage(), start, end);
```

```
}

private Date nextDay (Date arg) {
   // foreign method - should be in Date
   Date result = new Date (arg.getTime());
   result.setDate(result.getDate() + 1);
   return result;
}
```

A general principle I use in Java is not use the set... methods on date, since they can easily lead to bugs of this nature. I do use it in nextDay, however, because it is a Foreign Method, and should really be on Date. Foreign methods have to treated with caution. They are not unreasonable if there only one or two of them, but they can easily get out of control. If you find you have created more than two foreign methods its time to use an extension instead — I'll come to that later.

The Big Charge Method

All of this is limbering up for the big problem, the three-argument charge method. Let me refresh you on what they look like.

```
Class ResidentialSite {
  protected Dollars charge(int usage, Date start, Date end) {

     Dollars result;
     double summerFraction;

     // Find out how much of period is in the summer
     if (start.after(_zone.summerEnd()) || end.before(_zone.summerStart()))
        summerFraction = 0;
     else if (!start.before(_zone.summerStart()) && !start.after(_zone.summerEnd()) &&
            !end.before(_zone.summerStart()) && !end.after(_zone.summerEnd()))
        summerFraction = 1;
     else { // part in summer part in winter
        double summerDays;
        if (start.before(_zone.summerStart()) || start.after(_zone.summerEnd())) {
          // end is in the summer
          summerDays = dayOfYear(end) - dayOfYear (_zone.summerStart()) + 1;
        } else {
          // start is in summer
          summerDays = dayOfYear(_zone.summerEnd()) - dayOfYear (start) + 1;
        };
        summerFraction = summerDays / (dayOfYear(end) - dayOfYear(start) + 1);
     };

     result =  new Dollars ((usage * _zone.summerRate() * summerFraction) +
        (usage * _zone.winterRate() * (1 - summerFraction)));


     result = result.plus(new Dollars (result.times(TAX_RATE)));

     Dollars fuel = new Dollars(usage * 0.0175);
     result = result.plus(fuel);

     result = new Dollars (result.plus(fuel.times(TAX_RATE)));

     return result;

  }

Class DisabilitySite {
  protected Dollars charge(int fullUsage, Date start, Date end) {
     Dollars result;
     double summerFraction;
     int usage = Math.min(fullUsage, CAP);

     if (start.after(_zone.summerEnd()) || end.before(_zone.summerStart()))
        summerFraction = 0;
     else if (!start.before(_zone.summerStart()) && !start.after(_zone.summerEnd()) &&
            !end.before(_zone.summerStart()) && !end.after(_zone.summerEnd()))
        summerFraction = 1;
     else {
        double summerDays;
        if (start.before(_zone.summerStart()) || start.after(_zone.summerEnd())) {
          // end is in the summer
          summerDays = dayOfYear(end) - dayOfYear (_zone.summerStart()) + 1;
        } else {
```

```
            // start is in summer
            summerDays = dayOfYear(_zone.summerEnd()) - dayOfYear (start) + 1;
         };
         summerFraction = summerDays / (dayOfYear(end) - dayOfYear(start) + 1);
      };

      result =  new Dollars ((usage * _zone.summerRate() * summerFraction) +
         (usage * _zone.winterRate() * (1 - summerFraction)));

      result = result.plus(new Dollars (Math.max(fullUsage - usage, 0) * 0.062));


      result = result.plus(new Dollars (result.times(TAX_RATE)));

      Dollars fuel = new Dollars(fullUsage * 0.0175);
      result = result.plus(fuel);
      result = new Dollars (result.plus(fuel.times(TAX_RATE).min(FUEL_TAX_CAP)));

      return result;
   }
```

Its easy for my eyes to glaze over with big methods like that, but as I run my eye over them I can see some similarities. The code I've highlighted is identical (probably cut and pasted) and is there to determine the value of the temp summerFraction. I can thus extract that method, and put the extracted method into Site.

The first step in extracting a method is to identify any variables referenced in the code that are local in scope to the routine. You can do this by eye, or by using a find on the local scope variables. The local scope variables are temps and parameters. In this start, end, and summerFraction are the ones used by the candidate extract. Next I need to consider if any of these values are altered. I treat as the height of bad taste to alter a parameter in Java, but I check anyway. The only one of the three to be altered is summerFraction. If you have one locally scoped variable that is altered, and that variable is used outside the extracted code, then it makes sense to make the extracted code have a return value. The temp sounds like a good name for the new method: `double summerFraction()`

Each locally scoped variable that is used needs to be passed into the new method as a parameter. SummerFraction is not altered between its initialization and the entry into to candidate extraction, so we don't need to pass it in, I can just initialize it within the new method. So the new method will have two parameters: double summerFraction(Date start, Date end).

I begin with just one class, I picked ResidentialSite at random. I create the new method in that class (I'll move it up to Site later). I first copy the candidate extraction, put it into a new method, and compile it. Then I remove the candidate extraction from the source method and replace it with a method that calls the new method. In this case I find all uses of summerFraction and replace them with references to the new method. Then I test to see if I have broken anything.

```
   protected Dollars charge(int usage, Date start, Date end) {

      Dollars result;

      result =  new Dollars ((usage * _zone.summerRate() * summerFraction(start,end)) +
         (usage * _zone.winterRate() * (1 - summerFraction(start,end))));


      result = result.plus(new Dollars (result.times(TAX_RATE)));

      Dollars fuel = new Dollars(usage * 0.0175);
      result = result.plus(fuel);

      result = new Dollars (result.plus(fuel.times(TAX_RATE)));

      return result;

   }


   private double summerFraction(Date start, Date end) {
      double summerFraction;
      if (start.after(_zone.summerEnd()) || end.before(_zone.summerStart()))
         summerFraction = 0;
      else if (!start.before(_zone.summerStart()) && !start.after(_zone.summerEnd()) &&
             !end.before(_zone.summerStart()) && !end.after(_zone.summerEnd()))
         summerFraction = 1;
```

```
    else { // part in summer part in winter
       double summerDays;
       if (start.before(_zone.summerStart()) || start.after(_zone.summerEnd())) {
         // end is in the summer
         summerDays = dayOfYear(end) - dayOfYear (_zone.summerStart()) + 1;
       } else {
         // start is in summer
         summerDays = dayOfYear(_zone.summerEnd()) - dayOfYear (start) + 1;
       };
       summerFraction = summerDays / (dayOfYear(end) - dayOfYear(start) + 1);
    };
    return summerFraction;
  }
```

All went well, so now I move the new method up to Site and compile. When I compile it complains that the method dayOfYear is not in Site (it was defined on the subclass). I could look into moving that up too, but I will do that later. For now I'll make an appropriate abstract method in Site (which means loosening the access control in the subclasses)

```
abstract int dayOfYear(Date arg);
```

I test again and all is good. Now I remove the similar looking code from DisabilitySite's charge method and replace with the appropriate call to summerFraction().

```
protected Dollars charge(int fullUsage, Date start, Date end) {
    Dollars result;
    int usage = Math.min(fullUsage, CAP);


    result =  new Dollars ((usage * _zone.summerRate() * summerFraction(start, end)) +
       (usage * _zone.winterRate() * (1 - summerFraction(start, end))));

    result = result.plus(new Dollars (Math.max(fullUsage - usage, 0) * 0.062));


    result = result.plus(new Dollars (result.times(TAX_RATE)));

    Dollars fuel = new Dollars(fullUsage * 0.0175);
    result = result.plus(fuel);
    result = new Dollars (result.plus(fuel.times(TAX_RATE).min(FUEL_TAX_CAP)));

    return result;
   }
```

Extracting a large method like that really helps the readibility of the code. If someone has used cut and paste when they shouldn't you can often do this.

Now its easier to see the differences between the methods. The disability case caps the amount sent in via a parameter. The later sections of code do not use this capped value, so I decided to make my next steps down there. Both methods have the two following lines in common

```
    Dollars fuel = new Dollars(fullUsage * 0.0175);
    result = result.plus(fuel);
```

As I did above I can remove the temp fuel with a new method.

```
Class DisabilitySite
  protected Dollars charge(int fullUsage, Date start, Date end) {
    Dollars result;
    int usage = Math.min(fullUsage, CAP);


    result =  new Dollars ((usage * _zone.summerRate() * summerFraction(start, end)) +
       (usage * _zone.winterRate() * (1 - summerFraction(start, end))));

    result = result.plus(new Dollars (Math.max(fullUsage - usage, 0) * 0.062));


    result = result.plus(new Dollars (result.times(TAX_RATE)));

    result = result.plus(fuelCharge(fullUsage));
    result = new Dollars
                 (result.plus(fuelCharge(fullUsage).times(TAX_RATE).min(FUEL_TAX_CAP)));

    return result;
  }

  protected Dollars fuelCharge() {
```

```
    return new Dollars(lastUsage() * FUEL_CHARGE_RATE);
  }

  protected static final double FUEL_CHARGE_RATE = 0.0175;
```

At first sight it may seem odd to remove the temporary variable. Again all I am doing is causing the fuelCharge to be calculated twice instead of once. Again my argument would be that it really does no harm, I can cache it later when I optimize. (You might say "why bother" and leave the temp in place. Keep that in mind during the next step.)

Now I will go at the next line, which is different in two methods.

```
class ResidentialSite {
  protected Dollars charge(int usage, Date start, Date end) {

     Dollars result;

     result =  new Dollars ((usage * _zone.summerRate() * summerFraction(start,end)) +
        (usage * _zone.winterRate() * (1 - summerFraction(start,end))));


     result = result.plus(new Dollars (result.times(TAX_RATE)));

     result = result.plus(fuelCharge(usage));

     result = new Dollars (result.plus(fuelCharge(usage).times(TAX_RATE)));

     return result;

    }

Class DisabilitySite {
  protected Dollars charge(int fullUsage, Date start, Date end) {
     Dollars result;
     int usage = Math.min(fullUsage, CAP);


     result =  new Dollars ((usage * _zone.summerRate() * summerFraction(start, end)) +
        (usage * _zone.winterRate() * (1 - summerFraction(start, end))));

     result = result.plus(new Dollars (Math.max(fullUsage - usage, 0) * 0.062));


     result = result.plus(new Dollars (result.times(TAX_RATE)));

     result = result.plus(fuelCharge(fullUsage));
     result = new Dollars
              (result.plus(fuelCharge(fullUsage).times(TAX_RATE).min(FUEL_TAX_CAP)));

     return result;
    }
```

Although they are different, they both do a similar thing. They both add the taxes for the fuel charge to the result. In this case I will extract the methods again, but this time I will have two separate new methods, one in each class.

```
class ResidentialSite {
  protected Dollars charge(int usage, Date start, Date end) {

     Dollars result;

     result =  new Dollars ((usage * _zone.summerRate() * summerFraction(start,end)) +
        (usage * _zone.winterRate() * (1 - summerFraction(start,end))));


     result = result.plus(new Dollars (result.times(TAX_RATE)));

     result = result.plus(fuelCharge(usage));

     result = result.plus(fuelChargeTaxes(usage));

     return result;

  }

  protected Dollars fuelChargeTaxes(int usage) {
     return new Dollars (fuelCharge(usage).times(TAX_RATE));
```

```
  }

Class DisabilitySite {
  protected Dollars charge(int fullUsage, Date start, Date end) {
     Dollars result;
     int usage = Math.min(fullUsage, CAP);


     result =  new Dollars ((usage * _zone.summerRate() * summerFraction(start, end)) +
        (usage * _zone.winterRate() * (1 - summerFraction(start, end))));

     result = result.plus(new Dollars (Math.max(fullUsage - usage, 0) * 0.062));


     result = result.plus(new Dollars (result.times(TAX_RATE)));

     result = result.plus(fuelCharge(fullUsage));
     result = result.plus(fuelChargeTaxes(fullUsage));

     return result;
  }

  protected Dollars fuelChargeTaxes(int usage) {
     return new Dollars (fuelCharge(usage).times(TAX_RATE).min(FUEL_TAX_CAP));
  }
```

My master plan is now coming apparent to me. Charge looks like it may turn out to be a *Template Method*, if so want to decompose it and turn it into a sequence of identical calls to methods that vary polymorphically. I haven't really looked to see if this will work for the whole method yet, but I might as well start that way. If two methods in different classes seems to do the same thing, I might as well give them the same signature.

You might also now see an advantage in why I didn't hang on to the fuel temporary variable earlier. If I had done that then that would be another locally scoped temp that I would have had to pass into the fuelChargeTaxes method. All those temps and parameters make life awkward. By replacing the temp with a method, I no longer pass it in, I just call the method. If later I need to cache the value of the method, that cache will work whenever the method is used.

Can you see that I could have done the same thing with the call to the three parameter charge method in the first place? Usage, start, and end can all be replaced with appropriate methods. I will do that later.

(You might wonder, why didn't I do that earlier. Here is a confession that you shouldn't really see in a book like this. I have always followed the habit of eliminating parameters when I refactor, but I never really knew why, it was just a habit. Only in writing this chapter did I realize why I did it.)

For now I will get back to working on this charge method. I have a game plan to make this a template method, where else can I get ready to do this? An obvious place is the taxes.

```
Class Site {

  protected Dollars taxes(Dollars arg) {
     return new Dollars (arg.times(TAX_RATE));
  }

  protected static final double TAX_RATE = 0.05;

Class ResidentialSite {
  protected Dollars charge(int usage, Date start, Date end) {

     Dollars result;

     result =  new Dollars ((usage * _zone.summerRate() * summerFraction(start,end)) +
        (usage * _zone.winterRate() * (1 - summerFraction(start,end))));


     result = result.plus(taxes(result));

     result = result.plus(fuelCharge(usage));

     result = result.plus(fuelChargeTaxes(usage));

     return result;
```

```
  }
Class DisabilitySite {
  protected Dollars charge(int fullUsage, Date start, Date end) {
     Dollars result;
     int usage = Math.min(fullUsage, CAP);


     result =  new Dollars ((usage * _zone.summerRate() * summerFraction(start, end)) +
        (usage * _zone.winterRate() * (1 - summerFraction(start, end))));

     result = result.plus(new Dollars (Math.max(fullUsage - usage, 0) * 0.062));


     result = result.plus(taxes(result));

     result = result.plus(fuelCharge(fullUsage));
     result = result.plus(fuelChargeTaxes(fullUsage));

     return result;
  }
```

The next step takes a little thought. An obvious next move would be to do something along these lines to disability site

```
  protected Dollars charge(int fullUsage, Date start, Date end) {
     Dollars result;
     int usage = Math.min(fullUsage, CAP);


     result =  baseCharge(usage);

     result = result.plus(overCapCharge (fullUsage - usage));


     result = result.plus(taxes(result));

     result = result.plus(fuelCharge(fullUsage));
     result = result.plus(fuelChargeTaxes(fullUsage));

     return result;
  }
```

But if I do that, the charge method will have to be different between the disability site and the residential site, foiling my master plan of making charge a template method. Although I only formed this master plan in the middle of refactoring this method, I still like it and want it to succeed (template methods are good). So I look for a refactoring that fits in with it. Such a move would mean extracting the highlighted code in the following.

```
Class DisabilitySite {
  protected Dollars charge(int fullUsage, Date start, Date end) {
     Dollars result;
     int usage = Math.min(fullUsage, CAP);


     result =  new Dollars ((usage * _zone.summerRate() * summerFraction(start, end)) +
        (usage * _zone.winterRate() * (1 - summerFraction(start, end))));

     result = result.plus(new Dollars (Math.max(fullUsage - usage, 0) * 0.062));


     result = result.plus(taxes(result));

     result = result.plus(fuelCharge(fullUsage));
     result = result.plus(fuelChargeTaxes(fullUsage));

     return result;
  }
```

If I do this I could make a single polymorphic method baseCharge(). The result looks like this.

```
Class DisabilitySite {
  protected Dollars charge(int fullUsage, Date start, Date end) {
     Dollars result;
     result =  baseCharge(fullUsage, start, end);
     result = result.plus(taxes(result));
     result = result.plus(fuelCharge(fullUsage));
     result = result.plus(fuelChargeTaxes(fullUsage));

     return result;
  }
```

```
  protected Dollars baseCharge(int arg, Date start, Date end) {
     int cappedUsage = Math.min(arg, CAP);

     Dollars result;
     result =  new Dollars (
        (cappedUsage * _zone.summerRate() * summerFraction(start, end)) +
        (cappedUsage * _zone.winterRate() * (1 - summerFraction(start, end)))
     );
     result = result.plus(new Dollars (Math.max(arg - cappedUsage, 0) * 0.062));
     return result;
  }
```

For ResidentialSite it looks like this.

```
 Class ResidentialSite {
  protected Dollars charge(int usage, Date start, Date end) {
     Dollars result;
     result = baseCharge(usage, start, end);
     result = result.plus(taxes(result));
     result = result.plus(fuelCharge(usage));
     result = result.plus(fuelChargeTaxes(usage));
     return result;
  }

  protected Dollars baseCharge(int usage, Date start, Date end) {
     return new Dollars ((usage * _zone.summerRate() * summerFraction(start,end)) +
        (usage * _zone.winterRate() * (1 - summerFraction(start,end))));
  }
```

Now the two charge methods are identical, so I can move them (it?) up to the site class.

```
 abstract class Site {
  protected Dollars charge(int usage, Date start, Date end) {
     Dollars result;
     result = baseCharge(usage, start, end);
     result = result.plus(taxes(result));
     result = result.plus(fuelCharge(usage));
     result = result.plus(fuelChargeTaxes(usage));
     return result;
  }
  abstract protected Dollars baseCharge (int usage, Date start, Date end);
  abstract protected Dollars fuelChargeTaxes(int usage);
```

I also have to create abstract methods for baseCharge and fuelChargeTaxes. Now I have a statement of how you create a charge that reads like documentation, even without comments!

Combining the Two Charge Methods

Now I want to combine the two single-argument charge methods, get rid of the temps and reduce the parameter list. The first target is the usage argument, which already has a method for it: lastUsage. To do this I need to find every reference to the string usage. If the reference is in a method call or declaration I remove it. If it is in some body code, I replace it with lastUsage(). This causes quite a lot of changes, but with the find and replace tools in editors it is actually quite easy to do.

```
 Class Site {
  public Dollars charge() {
     Date end = lastReading().date();
     Date start = nextDay(previousReading().date());
     return charge(start, end);
  }
  protected Dollars charge(Date start, Date end) {
     Dollars result;
     result = baseCharge(start, end);
     result = result.plus(taxes(result));
     result = result.plus(fuelCharge());
     result = result.plus(fuelChargeTaxes());
     return result;
  }
  abstract protected Dollars baseCharge (Date start, Date end);
  abstract protected Dollars fuelChargeTaxes();
  protected Dollars fuelCharge() {
     return new Dollars(lastUsage() * 0.0175);
  }

 Class DisabilitySite {
  protected Dollars baseCharge(Date start, Date end) {
```

```
    int cappedUsage = Math.min(lastUsage(), CAP);

    Dollars result;
    result =  new Dollars (
       (cappedUsage * _zone.summerRate() * summerFraction(start, end)) +
       (cappedUsage * _zone.winterRate() * (1 - summerFraction(start, end)))
    );

    result = result.plus(new Dollars (Math.max(lastUsage() - cappedUsage, 0) * 0.062));
    return result;
   }
  protected Dollars fuelChargeTaxes() {
    return new Dollars (fuelCharge().times(TAX_RATE).min(FUEL_TAX_CAP));
  }

 Class ResidentialSite {
  protected Dollars baseCharge(Date start, Date end) {
    return new Dollars ((lastUsage() * _zone.summerRate() * summerFraction(start,end)) +
       (lastUsage() * _zone.winterRate() * (1 - summerFraction(start,end))));
  }
  protected Dollars fuelChargeTaxes() {
    return new Dollars (fuelCharge().times(TAX_RATE));
  }
```

The other parameters to work on are the start and end dates. I can do this quite easily as they are only used in determining the summerFraction. I could replace them with methods such as lastPeriodStart and lastPeriodEnd, but there is something else I would like to do.

Starts and ends tend to come in pairs, and that pair has a meaning all of itself. We are talking here about a period of time. The start and the end are just attributes of this period, and I prefer to recognize the period as a *Whole Object* and to preserve this whole object in the code. The whole object for any pair of values marked start and end is a *Range*. For a pair of dates in a typed language I will use a specific class DateRange. This is a common class for me, and I often have one lying around. In this case I will build it up from scratch as I need it. It starts simply as an encapsulated record.

```
import java.util.Date;
class DateRange {
  public DateRange(Date start, Date end) {
    _start = start;
    _end = end;
  }
  public Date end() {
    return _end;
  }
  public Date start() {
    return _start;
  }
  private Date _end;
  private Date _start;
}
```

Now I need a method to create the lastPeriod.

```
class Site {
  public DateRange lastPeriod() {
    return new DateRange (nextDay(previousReading().date()), lastReading().date());
  }
```

And I can modify summerFraction to use it.

```
class Site {
  protected double summerFraction() {
    double result;          // I also changed this name to make it fit my normal usage
    if (
         lastPeriod().start().after(_zone.summerEnd()) ||
         lastPeriod().end().before(_zone.summerStart())
    )
       result = 0;
    else if (
         !lastPeriod().start().before(_zone.summerStart()) &&
         !lastPeriod().start().after(_zone.summerEnd()) &&
         !lastPeriod().end().before(_zone.summerStart()) &&
         !lastPeriod().end().after(_zone.summerEnd())
    )
       result = 1;
    else { // part in summer part in winter
       double summerDays;
       if (
```

```
            lastPeriod().start().before(_zone.summerStart()) ||
            lastPeriod().start().after(_zone.summerEnd())
        ) {
          // end is in the summer
          summerDays = dayOfYear(lastPeriod().end()) -
                                  dayOfYear (_zone.summerStart()) + 1;
        } else {
          // start is in summer
          summerDays = dayOfYear(_zone.summerEnd()) -
                                  dayOfYear (lastPeriod().start()) + 1;
        };
        result = summerDays / (dayOfYear(lastPeriod().end()) -
                               dayOfYear(lastPeriod().start()) + 1);
    };
    return result;
    }

class ResidentialSite extends Site {
    protected Dollars baseCharge() {
    return new Dollars ((lastUsage() * _zone.summerRate() * summerFraction()) +
       (lastUsage() * _zone.winterRate() * (1 - summerFraction())));
    }
class DisabilitySite extends Site {
    protected Dollars baseCharge() {
    int cappedUsage = Math.min(lastUsage(), CAP);

    Dollars result;
    result =  new Dollars ((cappedUsage * _zone.summerRate() * summerFraction()) +
       (cappedUsage * _zone.winterRate() * (1 - summerFraction())));

    result = result.plus(new Dollars (Math.max(lastUsage() - cappedUsage, 0) * 0.062));
    return result;
    }
```

Now I can merge the two charge methods

```
public Dollars charge() {
   Dollars result;
   result = baseCharge();
   result = result.plus(taxes(result));
   result = result.plus(fuelCharge());
   result = result.plus(fuelChargeTaxes());
   return result;
}
```

The taxes method doesn't really need an argument.

```
public Dollars charge() {
   Dollars result;
   result = baseCharge();
   result = result.plus(taxes());
   result = result.plus(fuelCharge());
   result = result.plus(fuelChargeTaxes());
   return result;
}

protected Dollars taxes() {
   return new Dollars (baseCharge().times(TAX_RATE));
}
```

So all we have is a simple sum

```
public Dollars charge() {
   return baseCharge().plus(taxes()).plus(fuelCharge()).plus(fuelChargeTaxes());
}
```

It doesn't look quite as good as it would if we could overload +, but it is still pretty clear.

Refactoring SummerFraction

The next thing I do is start looking though the methods of the three classes in the browser. I'm looking for something that looks over-complicated. The first method that catches my eye is summerFraction

```
class Site {
  protected double summerFraction() {
    double result;
    if (
```

```
        lastPeriod().start().after(_zone.summerEnd()) ||
        lastPeriod().end().before(_zone.summerStart())
        )
        result = 0;
    else if (
        !lastPeriod().start().before(_zone.summerStart()) &&
        !lastPeriod().start().after(_zone.summerEnd()) &&
        !lastPeriod().end().before(_zone.summerStart()) &&
        !lastPeriod().end().after(_zone.summerEnd())
        )
        result = 1;
    else { // part in summer part in winter
        double summerDays;
        if (
          lastPeriod().start().before(_zone.summerStart()) ||
          lastPeriod().start().after(_zone.summerEnd())
          ) {
          // end is in the summer
          summerDays = dayOfYear(lastPeriod().end()) -
                dayOfYear (_zone.summerStart()) + 1;
        } else {
          // start is in summer
          summerDays = dayOfYear(_zone.summerEnd()) -
              dayOfYear (lastPeriod().start()) + 1;
        };
        result = summerDays / (dayOfYear(lastPeriod().end()) -
            dayOfYear(lastPeriod().start()) + 1);
    };
    return result;
   }
```

There are a lot of conditionals here, which are hard to fit on this page. I will decompose the conditionals. I do this by extracting a method from each part of the conditional statement.

```
protected double summerFraction() {
    double result;
    if (isLastPeriodOutsideSummer())
        result = 0;
    else if (
            !lastPeriod().start().before(_zone.summerStart()) &&
            !lastPeriod().start().after(_zone.summerEnd()) &&
            !lastPeriod().end().before(_zone.summerStart()) &&
            !lastPeriod().end().after(_zone.summerEnd())
          )
        result = 1;
    else { // part in summer part in winter
        double summerDays;
        if (
          lastPeriod().start().before(_zone.summerStart()) ||
          lastPeriod().start().after(_zone.summerEnd())
        ) {
          // end is in the summer
          summerDays = dayOfYear(lastPeriod().end()) -
                dayOfYear (_zone.summerStart()) + 1;
        } else {
          // start is in summer
          summerDays = dayOfYear(_zone.summerEnd()) -
                dayOfYear (lastPeriod().start()) + 1;
        };
        result = summerDays / (dayOfYear(lastPeriod().end()) -
              dayOfYear(lastPeriod().start()) + 1);
    };
    return result;
  }

protected boolean isLastPeriodOutsideSummer() {
    return lastPeriod().start().after(_zone.summerEnd()) ||
        lastPeriod().end().before(_zone.summerStart());
}
```

As I look at the isLastPeriodOutsideSummer method I think that I should be able to simply this considerably by using the periods as whole objects. In this method I really want to know if the lastPeriod has no overlap with the zone's summer. The first step would be to get zone to be able to tell you its summer as a DateRange.

```
Class Zone {
  public DateRange summer() {
    return new DateRange (_summerStart, _summerEnd);
  }
```

I can then rewrite isLastPeriodOutsideSummer

```
   protected boolean isLastPeriodAllSummer() {
      return lastPeriod().start().after(_zone.summer().end()) ||
         lastPeriod().end().before(_zone.summer().start());
   }
```

As such that is no improvement. But now I can write a disjoint method for DateRange,

```
  Class DateRange
  public boolean disjoint(DateRange arg) {
      return arg.start().after(_end) || arg.end().before(_start);
   }
```

and make isLastPeriodOutsideSummer much simpler

```
   protected boolean isLastPeriodOutsideSummer() {
      return _zone.summer().disjoint(lastPeriod());
   }
```

In fact I don't think the body of isLastPeriodOutsideSummer is any less communicative than the method name, so I will inline it back into summerFraction.

```
   protected double summerFraction() {
      double result;
      if (_zone.summer().disjoint(lastPeriod()))
         result = 0;
      else if (
             !lastPeriod().start().before(_zone.summerStart()) &&
             !lastPeriod().start().after(_zone.summerEnd()) &&
             !lastPeriod().end().before(_zone.summerStart()) &&
             !lastPeriod().end().after(_zone.summerEnd())
           )
         result = 1;
      else { // part in summer part in winter
         double summerDays;
         if (
           lastPeriod().start().before(_zone.summerStart()) ||
           lastPeriod().start().after(_zone.summerEnd())
         ) {
           // end is in the summer
           summerDays = dayOfYear(lastPeriod().end()) -
                 dayOfYear (_zone.summerStart()) + 1;
         } else {
           // start is in summer
           summerDays = dayOfYear(_zone.summerEnd()) -
                 dayOfYear (lastPeriod().start()) + 1;
         };
         result = summerDays / (dayOfYear(lastPeriod().end()) -
               dayOfYear(lastPeriod().start()) + 1);
      };
      return result;
   }
```

I get the strong feeling that I can make this whole method into a method on DateRange, I will keep that goal in mind as I continue to decompose the method. I'll do the next conditional. This is pretty complicated and as my brain starts to hurt from figuring out what it is doing I look at the result. The result is effectively saying that the lastPeriod is entirely within the summer. Thus if I write a contains method on DateRange

```
  Class DateRange {
   public boolean contains(DateRange arg) {
      return arg.start().after(_start) && arg.end().before(_end);
   }
```

then I can rewrite it as

```
   protected double summerFraction() {
      double result;
      if (_zone.summer().disjoint(lastPeriod()))
         result = 0;
      else if (_zone.summer().contains(lastPeriod()))
         result = 1;
      else { // part in summer part in winter
         double summerDays;
         if (
           lastPeriod().start().before(_zone.summerStart()) ||
           lastPeriod().start().after(_zone.summerEnd())
         ) {
           // end is in the summer
           summerDays = dayOfYear(lastPeriod().end()) -
```

```
                dayOfYear (_zone.summerStart()) + 1;
        } else {
          // start is in summer
          summerDays = dayOfYear(_zone.summerEnd()) -
                dayOfYear (lastPeriod().start()) + 1;
        };
        result = summerDays / (dayOfYear(lastPeriod().end()) -
              dayOfYear(lastPeriod().start()) + 1);
    };
    return result;
  }
```

As I look at the next bit of code I see that the code is doing one thing if the start is within the summer period, and another if the end is within the summer. What happens if neither are within the summer, that is the summer is contained within the last period. The code is written with the assumption that that cannot happen. Again none of the test cases probe it (I need to find a new tester). I add a test case to probe it, and indeed it fails. As I refactor this code I will fix that bug.

To solve this best I need to step back a bit. If I think about this as a manipulation of date ranges then I can solve it by asking what the length of the last period is, and what the length of the overlap range between the last period and the summer is. I can substitute this algorithm for the existing one. Before I can do this I need to add some further behavior to DateRange to determine the intersection of two dateRanges and to determine the length of a dateRange.

Extending Date

To determine the length of a date range I need to be able to subtract two dates. Sadly the Date class in java does not give me this feature, hence this use of dayOfYear which is really a foreign method. I need to make a new series of foreign methods on date. The amount of foreign methods I will need is too much and will soon get out of hand. What I really need to do is to fix the Date class. Since I cannot get at the Date class, I can deal with it by making an *extension* for it. I can do this is two ways, either by subclassing Date or by making a *decorator* for Date. The easiest way seems to be to use a subclass. I begin with defining just the suitable constructors.

```
import java.util.Date;
class MfDate extends Date implements Cloneable{

  public MfDate (Date arg) {
     super (arg.getTime());
    }

    public MfDate (String dateString) {
     super (dateString);
    };
}
```

Whenever I create an extension I provide a constructor that takes what I'm extending as an argument. This makes it easy for code to switch between the two if needed. I've also provided the constructor for String since I know I use that in my test code.

At this point I have to decide: do I just use the extension where I need it (by converting to MfDate within certain methods) or do I use it everywhere. If I only use it where I need it I will be forever jumping back and forth between Date and MfDate and getting confused. If I change it everywhere I really do need to change it everywhere. Well my code is not too big and I do have a global find capability. So I use the global find to find every occurrence of Date.

There is only one point where there is a problem.

```
Class Site
  private Date nextDay (Date arg) {
     // foreign method - should be in Date
     Date result = new Date (arg.getTime());
     result.setDate(result.getDate() + 1);
     return result;
  }
```

If course I do need to move this to MfDate, now that I have created the extension. But for the moment I will fix the problem, compile and test, and then move it. I don't want too long a gap between tests. I could solve this by defining a constructor that takes a long argument, but what I really want here is a copy. So I would do better by giving MfDate a copy method.

```
import java.util.Date;
class MfDate extends Date implements Cloneable{

  public Object clone() {
     try {
        return super.clone();
     } catch (CloneNotSupportedException e) {
        //should not happen
        throw new InternalError(e.toString());
     }
  }

class Site
  private MfDate nextDay (MfDate arg) {
     // foreign method - should be on Date
     MfDate result = (MfDate) arg.clone();
     result.setDate(result.getDate() + 1);
     return result;
  }
```

That works, but I don't like the fact that the client of MfDate has to be responsible for the downcast. I can avoid that making MfDate encapsulate the downcast for the client.

```
Class MfDate
  public MfDate copy() {
        return (MfDate) clone();
  }

Class Site
  private MfDate nextDay (MfDate arg) {
     // foreign method - should be on Date
     MfDate result = arg.copy();
     result.setDate(result.getDate() + 1);
     return result;
  }
```

With that the system recompiles using MfDates everywhere.

Now I might as well move the foreign method to its proper home. To move a method you need to create it in the new place, adjusting the code as necessary.

```
Class MfDate
  public MfDate nextDay() {
     MfDate result = copy();
     result.setDate(result.getDate() + 1);
     return result;
  }
```

Next you need to find all the references to the original method and replace them with calls to the new method. There are two ways to do this in Java environments. You can either do a search and replace, or you can remove the old method, and let the compiler find where you need to make changes. There was one reference.

```
Class Site
  public DateRange lastPeriod() {
     return new DateRange (previousReading().date().nextDay(), lastReading().date());
  }
```

Whichever way you do the replacement make sure you remove the original method before you compile and test. Otherwise if you miss one you can get some funny results. Also look to see if the method is redefined anywhere within the inheritance hierarchy, the compiler won't catch that either.

To do the date subtraction I need to use the dayOfYear method currently in ResidentialSite and DisabilitySite. These methods are identical and are both foreign methods that should really by on MfDate. So I will move them over. First I move DayOfYear to MfDate.

```
Class MfDate {
int dayOfYear() {
     int result;
```

```
      switch (getMonth()) {
         case 0:
           result = 0;
           break;
         case 1:
           result = 31;
           break;
         case 2:
           result = 59;
           break;
         case 3:
           result = 90;
           break;
         case 4:
           result = 120;
           break;
         case 5:
           result = 151;
           break;
         case 6:
           result = 181;
           break;
         case 7:
           result = 212;
           break;
         case 8:
           result = 243;
           break;
         case 9:
           result = 273;
           break;
         case 10:
           result = 304;
           break;
         case 11:
           result = 334;
           break;
         default :
           throw new IllegalArgumentException();
      };
      result += getDate();

      //check leap year
      if ((getYear()%4 == 0) && ((getYear() % 100 != 0) || (getYear() % 400 == 0))) {
         result++;
      };

      return result;
     }
```

Still an ugly method, but I will deal with that later. Now I find all places that call it, as it turns out they are within summerFraction.

```
  protected double summerFraction() {
      double result;
      if (_zone.summer().disjoint(lastPeriod()))
         result = 0;
      else if (_zone.summer().contains(lastPeriod()))
         result = 1;
      else { // part in summer part in winter
         double summerDays;
         if (
           lastPeriod().start().before(_zone.summerStart()) ||
           lastPeriod().start().after(_zone.summerEnd())
         ) {
           // end is in the summer
           summerDays = lastPeriod().end().dayOfYear() -
                 _zone.summerStart().dayOfYear() + 1;
         } else {
           // start is in summer
           summerDays = _zone.summerEnd().dayOfYear() -
                 lastPeriod().start().dayOfYear() + 1;
         };
         result = summerDays / (lastPeriod().end().dayOfYear() -
               lastPeriod().start().dayOfYear() + 1);
      };
      return result;
     }
```

Then I remove dayOfYear from ResidentialSite and DisabilitySite, remove the abstract method declaration I had put on Site, compile and test.

Now I can get ready to do the date subtraction. I do, however, have a little problem. The date manipulations in summerFraction assume that periods do not cross year boundaries. A date subtraction routine should work with multiple years. Do I implement for the more general case, or just the simpler case present in the system I am refactoring? It seems like a dangerous assumption to me, but for the moment I will leave it as it is (with an error check). I can come back and fix that later. (The leap years make it not completely trivial.)

```
public int minus(MfDate arg) {
   requireSameYear (arg);          // TK fix this to cross years
   return dayOfYear() - arg.dayOfYear();
}

private void requireSameYear(MfDate arg) {
   if (getYear() != arg.getYear())
      throw new IllegalArgumentException ("Arguments must be in same year");
}
```

Now I can define length for a DateRange

```
class DateRange
  public int length() {
     return _end.minus(_start) + 1;
  }
```

The next thing I need to do is to define an intersection method for DateRange.

```
public DateRange intersection(DateRange arg) {
   MfDate newStart = (_start.after(arg.start())) ?
      _start :
      arg.start();
   MfDate newEnd = (_end.before(arg.end())) ?
      _end:
      arg.end();
   return new DateRange(newStart, newEnd);
}
```

Now (finally) I am ready to do substitute the algorithms. This kind of refactoring can often be a bigger jump than most refactorings. Rather than make small, behavior preserving transformations, I am making a larger transformation which I hope will be behavior preserving. Errors do occur, and I find this refactoring can often lead to debugging.

Here is my first shot at the new summerFraction

```
protected double summerFraction() {
   DateRange periodInSummer = lastPeriod().intersection(_zone.summer());
   return periodInSummer.length() / lastPeriod().length();
}
```

It didn't work, several test cases failed. In most refactoring my reaction to such a failure is to back out and try a smaller step, but algorithm substitution doesn't really lend itself to smaller steps. One thing I can do to help debugging is to reintroduce the old version summerFraction under the name oldSummerFraction. I can then use it to help me debug by alerting me whenever the result of summerFraction and oldSummerFraction differ. Tk check code.

```
protected double summerFraction() {
   DateRange periodInSummer = lastPeriod().intersection(_zone.summer());
   double result = periodInSummer.length() / lastPeriod().length();
   if (result != oldSummerFraction()) System.out.println ("new sf was " +
String.valueOf(result) + " old was " + String.valueOf (oldSummerFraction()) + " for " +
}
```

A little debugging quickly shows me that I am getting a lot of length zero summer periods when I shouldn't. The problem lies in using integer division; I need to use a cast.

```
protected double summerFraction() {
   DateRange periodInSummer = lastPeriod().intersection(_zone.summer());
   return (double) periodInSummer.length() / lastPeriod().length();
}
```

Now I get a different series of errors, all involving ranges with negative lengths. These are caused by the intersection method generating ranges whose start is after the end. I could treat these as errors, but in practice I've found that it is all right to allow these, treating them as empty ranges.

```
class DateRange
  public boolean isEmpty() {
     return _start.after(_end);
  }
```

I need to adjust length to take this into account.

```
Class DateRange
  public int length() {
     if (isEmpty()) return 0;
     return _end.minus(_start) + 1;
  }
```

With that the tests work, including the one I added to probe for the bug that existed in the old version.

Refactoring the Base Charge

The next item to catch my eye is the baseCharge methods on ResidentialSite and DisabilitySite

```
class ResidentialSite
  protected Dollars baseCharge() {
     return new Dollars ((lastUsage() * _zone.summerRate() * summerFraction()) +
        (lastUsage() * _zone.winterRate() * (1 - summerFraction())));
  }

class DisabilitySite
  protected Dollars baseCharge() {
     int cappedUsage = Math.min(lastUsage(), CAP);

     Dollars result;
     result =  new Dollars ((cappedUsage * _zone.summerRate() * summerFraction()) +
        (cappedUsage * _zone.winterRate() * (1 - summerFraction())));

     result = result.plus(new Dollars (Math.max(lastUsage() - cappedUsage, 0) * 0.062));
     return result;
  }
```

The highlighted section is similar to both methods and can be extracted into the superclass. The difference is that the disabilitySite caps the usage before applying this calculation while the residential site does not. I can deal with this by extracting and parameterizing the method.

```
Class Site
  Dollars residentialBaseCharge (int usage) {
     return new Dollars ((usage * _zone.summerRate() * summerFraction()) +
        (usage * _zone.winterRate() * (1 - summerFraction())));
  }

class ResidentialSite
  protected Dollars baseCharge() {
     return residentialBaseCharge (lastUsage());
  }

class DisabilitySite
  protected Dollars baseCharge() {
     int cappedUsage = Math.min(lastUsage(), CAP);

     Dollars result;
     result =  residentialBaseCharge (cappedUsage);

     result = result.plus(new Dollars (Math.max(lastUsage() - cappedUsage, 0) * 0.062));
     return result;
  }
```

As I look at this code I wonder whether the zone should not calculate the residentialBaseCharge. To do this I would have to move the behavior for summerFraction over there as well, and send it the usage and the lastPeriod as parameters. I don't have a strong feeling about it at the moment, but it would be useful if we had some zones with different factors than the summer period and the two rates. At the moment the site needs to know a lot about the zone, while if I moved the behavior over to zone it would only need to work with an int and a dateRange. It would also pull some behavior out of the Site class, which is getting fairly involved now.

To be honest it seems six of one and half a dozen of the other to me, and in many cases I would leave it as it is for the moment. Since I'm demonstrating the techniques though, I might as well do it.

To move the residentialBaseCharge over to zone I look at the methods that are called by residentialBaseCharge. For each one I have to decide: do I move over the result of the method as a parameter, or do I move over the whole method. I decide to move over summerFraction and send in the usage and the period as parameters.

I do this by putting the two methods into zone, adjusting them to their new home and compiling. Then I find all the references to the moved methods by commenting them out and seeing where the compiler complains. I fix the problems, compile and test. Then I remove the commented out methods.

```
Class Zone
  double summerFraction(DateRange usagePeriod) {
     DateRange periodInSummer = usagePeriod.intersection(summer());
     return (double) periodInSummer.length() / usagePeriod.length();
  }

  Dollars baseCharge (int usage, DateRange usagePeriod) {
     return new Dollars ((usage * _summerRate * summerFraction(usagePeriod)) +
        (usage * _winterRate * (1 - summerFraction(usagePeriod))));
  }

Class ResidentialSite
  protected Dollars baseCharge() {
     return _zone.baseCharge (lastUsage(), lastPeriod());
  }

Class DisabilitySite
  protected Dollars baseCharge() {
     int cappedUsage = Math.min(lastUsage(), CAP);

     Dollars result;
     result =  _zone.baseCharge (cappedUsage, lastPeriod());

     result = result.plus(new Dollars (Math.max(lastUsage() - cappedUsage, 0) * 0.062));
     return result;
  }
```

I can do some more with disabilitySite's baseCharge method. First I can eliminate the cappedUsage temp with a method.

```
Class DisabilitySite
  protected Dollars baseCharge() {
     Dollars result;
     result =  _zone.baseCharge (usageBelowCap(), lastPeriod());
     result = result.plus(new Dollars (Math.max(lastUsage() -
          usageBelowCap(), 0) * 0.062));
     return result;
  }

  protected int usageBelowCap() {
     return Math.min(lastUsage(), CAP);
  }
```

I do similar for the amount above the cap, and deal with the magic number.

```
   protected Dollars baseCharge() {
      Dollars result;
      result =  _zone.baseCharge (usageBelowCap(), lastPeriod());
      result = result.plus(new Dollars (usageAboveCap() * ABOVE_CAP_RATE));
      return result;
   }

   protected int usageAboveCap() {
      return Math.max(lastUsage() - usageBelowCap(), 0);
   }

   private static final double ABOVE_CAP_RATE = 0.062;
```

With that Site and its subclasses are pretty well factored. All the methods are small and understandable. You might not choose the same refactorings as I did. In the end what counts is what is most understandable to your team. I find very small methods easier to deal with, but you might prefer a larger granularity.

Fixing up MfDate and DateRange

I do some more looking at the classes I have been working on and spot two other methods to clean up. First is DateRange's intersection

```
public DateRange intersection(DateRange arg) {
   MfDate newStart = (_start.after(arg.start())) ?
      _start :
      arg.start();
   MfDate newEnd = (_end.before(arg.end())) ?
      _end:
      arg.end();
   return new DateRange(newStart, newEnd);
}
```

I can improve this by making a latest and earliest for MfDate.

```
Class DateRange
public DateRange intersection(DateRange arg) {
    return new DateRange(
         MfDate.latest(_start, arg.start()), MfDate.earliest(_end, arg.end()));
    }

Class MfDate
 public static MfDate earliest(MfDate arg1, MfDate arg2) {
    return (arg1.before(arg2)) ?
       arg1 :
       arg2;
 }

 public static MfDate latest(MfDate arg1, MfDate arg2) {
    return (arg1.after(arg2)) ?
       arg1 :
       arg2;
 }
```

A bigger looking problem is dayOfYear.

```
int dayOfYear() {
    int result;
    switch (getMonth()) {
       case 0:
         result = 0;
         break;
       case 1:
         result = 31;
         break;
       case 2:
         result = 59;
         break;
       case 3:
         result = 90;
         break;
       case 4:
         result = 120;
         break;
       case 5:
         result = 151;
         break;
       case 6:
         result = 181;
         break;
       case 7:
         result = 212;
         break;
       case 8:
         result = 243;
         break;
       case 9:
         result = 273;
         break;
       case 10:
         result = 304;
         break;
       case 11:
         result = 334;
         break;
       default :
         throw new IllegalArgumentException();
    };
```

```
      result += getDate();

      //check leap year
      if ((getYear()%4 == 0) && ((getYear() % 100 != 0) || (getYear() % 400 == 0))) {
         result++;
      };

      return result;
   }
```

The long case statement takes up a lot of vertical space (and thus scrolls off the bottom of my browser). Another alternative is to use a *searching literal*.

```
   int dayOfYear() {
      int result;
      int[] monthNumbers = {0, 31, 59, 90, 120, 151, 181, 212, 243, 273, 304, 334};
      result = monthNumbers[getMonth()];
      result += getDate();

      //check leap year
      if ((getYear()%4 == 0) && ((getYear() % 100 != 0) || (getYear() % 400 == 0))) {
         result++;
      };

      return result;
   }
```

I will remove the temp.

```
   int dayOfYear() {
      int result;
      result = daysToStartOfMonth();
      result += getDate();

      //check leap year
      if ((getYear()%4 == 0) && ((getYear() % 100 != 0) || (getYear() % 400 == 0))) {
         result++;
      };

      return result;
   }

   private int daysToStartOfMonth() {
      int[] monthNumbers = {0, 31, 59, 90, 120, 151, 181, 212, 243, 273, 304, 334};
      return monthNumbers[getMonth()];
   }
```

The leap year determination can also be extracted.

```
   int dayOfYear() {
      int result = daysToStartOfMonth() + getDate();
      if (isLeapYear()) result++;
      return result;
   }

   boolean isLeapYear() {
      return (getYear()%4 == 0) && ((getYear() % 100 != 0) || (getYear() % 400 == 0));
   }
```

In doing this I noticed another bug, the leap year will add one to the result even if the date is before the 28 Feb. I add a test to confirm and fix the bug.

```
  Class MfDate
   int dayOfYear() {
      int result = daysToStartOfMonth() + getDate();
      if (isLeapYear() & this.after(new Date (getYear(), 1, 28))) result++;
      return result;
   }
```

While I'm working on date I would like to make the date subtraction work across years. I'm too lazy to figure out the algorithm, so I pinch it from the Smalltalk image

```
  Class MfDate
   public int minus(MfDate arg) {
      return (getYear() == arg.getYear()) ?
         dayOfYear() - arg.dayOfYear() :     // shortcut
         daysSince1901() - arg.daysSince1901();
   }

  public int daysSince1901(){
```

```
    if (getYear() < 1) throw new IllegalArgumentException();
    int result;
    int yearIndex = getYear() - 1;
    result = yearIndex * 365;
    result += yearIndex / 4;                        // ordinary leap years
    result += (yearIndex + 300) / 400;              // leap_centuries
    result -= yearIndex / 100;                      // non-leap centuries
    result += dayOfYear() - 1;
    return result;
   }
```

I will leave it not working for the year 1900. I haven't tested to see if any of this works before the Java epoch (Jan 1 1970) in any case. Such dates are outside the current requirements of this program, so there's no need to worry about them just now.

All of this work has just combined together the DisabilitySite and ResidentialSite classes. Now its time to take another Site and refactor it into the Site hierarchy. I will now work on LifelineSite.

I begin by making LifelineSite a subclass of Site. The compiler complains that I haven't defined Site's abstract methods, so I put in some placeholders. It's important to throw exceptions here, I've been bitten before by doing nothing and forgetting that I should have put some real code in here.

```
public class LifelineSite extends Site {
  protected Dollars baseCharge() {
     throw new AbstractMethodError("undefined baseCharge");
  }
  protected Dollars fuelChargeTaxes () {
     throw new AbstractMethodError("undefined fuelChargeTaxes");
  }
```

More seriously it complains because Site does not have a no-argument constructor. Site currently has a Zone but Lifeline Sites do not have zones. For the moment I will create a Lifeline site with a null Zone.

```
class LifelineSite {
  public LifelineSite() {
     super (null);
  };
```

First I will look at how the Site handles readings. LifelineSite does it in a different way to that for the two prior sites. It adds the readings to the beginning instead of the end of the array.

```
   public void addReading(Reading newReading) {
      Reading[] newArray = new Reading[_readings.length + 1];
      System.arraycopy(_readings, 0, newArray, 1, _readings.length);
      newArray[0] = newReading;
      _readings = newArray;
   }
```

The charge method thus also works differently

```
   public Dollars charge() {
      int usage = _readings[0].amount() - _readings[1].amount();
      return charge(usage);
   }
```

It also does not compute a period for the charge.

As I inspect the methods I think that if I remove the readings array and alter the charge method to use lastReading() and previousReading() the thing will still work. I can test that hypothesis by changing it and running the tests. I remove the field _readings in LifelineSite, and remove the addReading method. That way I will inherit the usual behavior from Site. Then I alter the charge method to make use of the new behavior.

```
public Dollars charge()
    {
    int usage = lastReading().amount() - previousReading().amount();
    return charge(usage);
    }
```

The compiler would tell me if anything else was using addReading or _readings and nothing was. The tests tell me if all is still working fine, and they come back OK.

In that step, as with the future ones, I am using the understanding I have gained of the Site's behavior through the previous refactoring to help me with this refactoring. I'm expecting LifelineSite to show a lot of similarity with the previous Sites. I won't be flattened if it doesn't, but I will be helped if it does.

I see that LifelineSite has its own TAX_RATE member. I can delete this, since the same value is on Site.

I now need to deal with charge() and compare it with Site's template method.

```
Class Site
  public Dollars charge() {
     return baseCharge().plus(taxes()).plus(fuelCharge()).plus(fuelChargeTaxes());
  }

Class LifelineSite
  private Dollars charge  (int usage) {

     double base = Math.min(usage,100) * 0.03;
     if (usage > 100) {
        base += (Math.min (usage,200) - 100) * 0.05;
     };
     if (usage > 200) {
        base += (usage - 200) * 0.07;
     };

     Dollars result = new Dollars (base);

     Dollars tax = new Dollars (result.minus(new Dollars(8)).
        max(new Dollars (0)).times(TAX_RATE));
     result = result.plus(tax);

     Dollars fuelCharge = new Dollars (usage * 0.0175);
     result = result.plus (fuelCharge);
     return result.plus (new Dollars (fuelCharge.times(TAX_RATE)));
  }
```

Site assumes four calculations added together: base, tax, fuel charge, and the tax on the fuel charge. The fuel charge stuff is an obvious first target. I started with replacing the highlighted code with method calls, but was caught out because I hadn't redefined fuelChargeTaxes. So I can start with just the fuelCharge.

```
  private Dollars charge  (int usage) {

     double base = Math.min(usage,100) * 0.03;
     if (usage > 100) {
        base += (Math.min (usage,200) - 100) * 0.05;
     };
     if (usage > 200) {
        base += (usage - 200) * 0.07;
     };

     Dollars result = new Dollars (base);

     Dollars tax = new Dollars (result.minus(new Dollars(8)).
        max(new Dollars (0)).times(TAX_RATE));
     result = result.plus(tax);

     result = result.plus (fuelCharge());
     return result.plus (new Dollars (fuelCharge().times(TAX_RATE)));
  }
```

Looking at the implementations for fuelChargeTaxes, I can see that the LifelineSite's method is the same as that for ResidentialSite. So I move ResidentialSite's method up to Site. I do that by simply cutting it from ResidentialSite and pasting it in Site. Then I compile and test. Once that is done I can remove the placeholder from DisabilitySite and call the method from charge.

```
  private Dollars charge  (int usage) {

     double base = Math.min(usage,100) * 0.03;
     if (usage > 100) {
        base += (Math.min (usage,200) - 100) * 0.05;
     };
     if (usage > 200) {
        base += (usage - 200) * 0.07;
     };
```

```
    Dollars result = new Dollars (base);

    Dollars tax = new Dollars (result.minus(new Dollars(8)).
       max(new Dollars (0)).times(TAX_RATE));
    result = result.plus(tax);

    result = result.plus (fuelCharge());
    return result.plus (fuelChargeTaxes());
}
```

Working upwards the next thing I see is the calculation for the taxes. It looks like I can extract that into taxes.

```
private Dollars charge  (int usage) {

    double base = Math.min(usage,100) * 0.03;
    if (usage > 100) {
       base += (Math.min (usage,200) - 100) * 0.05;
    };
    if (usage > 200) {
       base += (usage - 200) * 0.07;
    };

    Dollars result = new Dollars (base);

    result = result.plus(taxes(result));

    result = result.plus (fuelCharge());
    return result.plus (fuelChargeTaxes());
}

protected Dollars taxes (Dollars base) {
    return new Dollars (base.minus(new Dollars(8)).
           max(new Dollars (0)).times(TAX_RATE));
}
```

The form does not exactly match the template, since I have to pass in the result to taxes as an argument. That's only a temporary problem and I will deal with it soon.

The top bit looks like LifelineSite's base charge method.

```
private Dollars charge  (int usage) {

    Dollars result = baseCharge();

    result = result.plus(taxes(result));

    result = result.plus (fuelCharge());
    return result.plus (fuelChargeTaxes());
}

protected Dollars baseCharge() {
    double result = Math.min(lastUsage(),100) * 0.03;
    if (lastUsage() > 100) {
       result += (Math.min (lastUsage(),200) - 100) * 0.05;
    };
    if (lastUsage() > 200) {
       result += (lastUsage() - 200) * 0.07;
    };

    return new Dollars (result);
}
```

All I need to do is fix the taxes method, and I can eliminate the charge method on LifelineSite.

```
Class Site
  public Dollars charge() {
    return baseCharge().plus(taxes()).plus(fuelCharge()).plus(fuelChargeTaxes());
  }

class LifelineSite
  protected Dollars taxes () {
    return new Dollars (baseCharge().minus(new Dollars(8)).
           max(new Dollars (0)).times(TAX_RATE));
  }
```

That all went very smoothly. The basic method was the same as the previous cases, probably they all shared a common heritage of cut and paste.

Refactoring LifelineSite's baseCharge

I think there is some simplification I can do with the baseCharge method, however. The code looks somewhat repetitive. I think I should be able to factor it with extracting a parameterized method. I start with the first bit of code.

```
protected Dollars baseCharge() {
   double result = usageUnder(100) * 0.03;
   if (lastUsage() > 100) {
      result += (Math.min (lastUsage(),200) - 100) * 0.05;
   };
   if (lastUsage() > 200) {
      result += (lastUsage() - 200) * 0.07;
   };

   return new Dollars (result);
}

protected int usageUnder(int limit) {
   return Math.min(lastUsage(),limit);
}
```

UsageUnder works for that bit, but I need to introduce the conditional and the previous value for it to work for the 200 limit.

```
protected Dollars baseCharge() {
   double result = usageInRange(0, 100) * 0.03;
   result += usageInRange (100,200) * 0.05;
   if (lastUsage() > 200) {
      result += (lastUsage() - 200) * 0.07;
   };

   return new Dollars (result);
}
protected int usageInRange(int start, int end) {
   if (lastUsage() > start) return Math.min(lastUsage(),end) - start;
   else return 0;
}
```

I can then apply it to the topmost part of the range

```
protected Dollars baseCharge() {
   double result = usageInRange(0, 100) * 0.03;
   result += usageInRange (100,200) * 0.05;
   result += usageInRange (200, Integer.MAX_VALUE) * 0.07;

   return new Dollars (result);
}
```

This all works, but there are few too many rules to using it. The programmer has to ensure that the values are set up so the lower number match the upper numbers, and that the top number is set to Integer.MAX_VALUE. I would prefer something where you could set things up with an array of bounds and values. I feel an object coming on. I would like it to work like this

```
//pseudo Java !
RateTable table = {  0.03, 100
                     0.05, 200
                     0.07};
return table.value(lastUsage());
```

I often like to think about how I would like to use an object before I try creating one. From this I can get a sense of what the methods look like. But I now have enough to try it out.

```
class RateTable {
    public RateTable(double[] table) {
    _table = table;
    }
    private double[] _table;
}
```

The key lies in its behavior. I need to move the usageInRange method over to it.

```
private int usageInRange(int amount, int start, int end) {
   if (amount > start) return Math.min(amount,end) - start;
   else return 0;
}
```

Then I need to create value method to work over the array. One possibility is something along the following lines.

```
// not working code!
public int value(int amount) {
   double result = 0;
   for (int i=0; i < _table.length; i += 2) {
      result += usageInRange(amount, _table[i], _table[i-2]) * _table [i+1]);
   }
   return new Dollars (result);
}
```

The trouble with this is that there is far too much special interpretation of the array indices, not to mention of how to fix it to support the maximum value, or how to deal with an array that would contain both reals and ints.

A better idea is to use two arrays. Just because the constructor only uses one doesn't mean the class can't change it into two.

```
public RateTable(double[] arg) {
   int arrayLengths = arg.length / 2 + 1;
   _rates = new double[arrayLengths];
   _limits = new int[arrayLengths];
   int argIndex = 0;
   for (int i = 0; i < (arrayLengths - 1); i++) {
      _rates[i] = arg[argIndex++];
      _limits[i] = (int) arg[argIndex++];
   };
   _rates[arrayLengths - 1] = arg [arg.length -1];
   _limits[arrayLengths - 1] = Integer.MAX_VALUE;
 }
```

That's a messy method, but it seems to set the rate table up in the right way. It makes value easier to write.

```
public Dollars value(int amount) {
    double result = 0;
    result = usageInRange(amount, 0, _limits[0]) * _rates[0];
    for (int i=1; i < _rates.length; i++)
       result += usageInRange(amount, _limits[i-1], _limits[i]) * _rates[i];
    return new Dollars (result);
   }
```

I can then alter baseCharge.

```
protected Dollars baseCharge() {
   double [] table = {     0.03, 100,
              0.05, 200,
              0.07};
   return new Dollars (new RateTable(table).value(lastUsage()));
}
```

Well it took a bit of fiddling to get the constructor to work but it does now work. Was it worth the change? I don't think so. The new class certainly makes it much easier to write baseCharge, but the new class is rather complicated to deal with. I'm sure I can refactor it into a better shape, but I'm not sure its worth the effort to simplify one method. For the moment I will change baseCharge back to what it was. I won't throw away RateTable for the moment — it might come in useful later.

A false move like this does happen from time to time in refactoring. You see something that looks like a simplification, and find out that it seems to make things more complex. In these cases you just have to chalk it up to experience and back out of the change. The aim is to make the code simpler, not more complicated.

Changing _readings to a Vector

At the moment _readings is a 1000 size array. Arrays are awkward in this situation. You just know that at some point someone is going to add the 1001th element. You also know that if you make the array too big in the first place (like Integer.MAX_VALUE) then you will waste a lot of memory. What we need is an array that can grow as we need it. Java has a Vector class for that very purpose.

_readings can be set up as a vector

```
private Vector _readings = new Vector();
```

I need to alter those methods that access it. To find those I do a find using the editor.

```
public void addReading(Reading newReading) {
   _readings.addElement(newReading);
}
private int firstUnusedReadingsIndex () {
   return _readings.size();
}
protected int lastUsage() {
   return lastReading().amount() - previousReading().amount();
}
public Reading lastReading() {
   return (Reading) _readings.lastElement();
}
public Reading previousReading() {
   return (Reading) _readings.elementAt(_readings.size() - 2);
}
```

Those do the trick and also make the code easier to read. FirstUnusedReadingsIndex is not necessary any more so I can remove it. The one problem with vectors is that you have to downcast anything you take out of it. So I ensure that lastReading and previousReading encapsulate the downcasting.

This ability to change the data structure of the class, without altering the interface, is one of the joys of an OO language. In performance tuning it is quite possible that we would find a hotspot in the access or update of the readings vector. Again we should be able to change its implementation easily to provide performance improvements at that time.

The way the Site class works, there is an assumption in the Site class about the readings, that is that the readings are in order of dates, earliest first. There is, however, nothing to stop someone from adding a reading that would violate this assumption. The class as an internal invariant which says that the readings are in date order. In a langugae such as Eiffel, we could code this invariant directly into the class. This is not so easy in Java. However we can improve matters by considering what operations could change the state of the invariant, causing it to become false. The only operation to do this is the addReading operation. We need to add a clause to addReading to check for incorrect dates.

```
public void addReading(Reading newReading) {
   if (newReading.date().before(lastReading().date()))
      // do something ;
   _readings.addElement(newReading);
}
```

What action should we take? The site could choose to insert the reading in the appropriate place, instead of adding it at the end, but that would invalidate previous uses of charge. It may be that later iterations of this program will give it the ability to handle these readings intelligently, but all it can do for the moment is throw and exception.

Now I've decided to throw an exception, I have to decide whether I throw a checked or unchecked exception. The Java texts emphasize that you should use checked exceptions, indeed they imply that you should rarely throw unchecked exceptions. I'm not so sure about this rule. Checked exceptions are good, in that you force the user to decide what to do when they go wrong, but they can lead to very cluttered code. Every calling program needs to decide how to handle the exception, if they cannot decide they have to propagate the exception, and the decision making.

I prefer to think about it in terms of Design By Contact. Is the fact that the date of the new reading be later than existing readings part of the pre-condition of the addReading method? If so then it is the callers responsibility to check that before the call addReading, and addReading should not throw a checked exception. AddReading should only throw an exception if you decide that it is addReading's responsibility to check for that condition.

It's hard to make a definitive answer from here, since it depends on the context of addReading from the overall program, and we are only looking at this section of the program. However since all the knowledge of whether it is a problem or not lies within the site, I will make it a checked exception.

```
public void addReading(Reading newReading) throws IncorrectReadingException {
 if (newReading.date().before(lastReading().date()))
    throw new IncorrectReadingException ("Reading is before previous reading");
 _readings.addElement(newReading);
}
```

The code complies, but runs into a problem when it executes. The first time this method is used, lastReading tries to read from an empty vector, and throws a NoSuchElementException. As I look at it I suppose I should alter lastReading to return a null if the _readings vector is empty, but I would still have to alter addReading to deal with the null. I could avoid that by creating a null object for reading, but that is a lot of effort for one case. So the simplest thing to do is

```
public void addReading(Reading newReading) throws IncorrectReadingException {
    if (!_readings.isEmpty() && newReading.date().before(lastReading().date()))
       throw new IncorrectReadingException ("Reading is before previous reading");
    _readings.addElement(newReading);
    }
```

If I need to adjust lastReading for an empty vector, I can do that later. The condition is rather long winded however, so I extract it.

```
public void addReading(Reading newReading) throws IncorrectReadingException {
   if (isNotLatestReading(newReading))
      throw new IncorrectReadingException ("Reading is before previous reading");
   _readings.addElement(newReading);
}

private boolean isNotLatestReading(Reading arg) {
   return !_readings.isEmpty() && arg.date().before(lastReading().date());
}
```

And, now I've added the check, I also add a test to check that it is working

```
class SiteTester
 void testIncorrectReading() throws Exception{
    Site subject = new ResidentialSite(Zone.get("B"));
    subject.addReading(new Reading (25, new MfDate ("8 Sep 1997")));
    boolean exceptionNotFound = true;
    try {
       subject.addReading(new Reading (125, new MfDate ("1 Sep 1997")));
    } catch (IncorrectReadingException e) {
       exceptionNotFound = false;
    }
    if (exceptionNotFound) addFailure ("Failed to spot incorrect reading");
 }
```

Adding BusinessSite to the Hierarchy

Now its time to work on the final class, BusinessSite. My first move is to make it a subclass of Site and to compile. It tells me it needs an implementation for baseCharge and a no-arg constructor. The former seems reasonable but the latter is irritating. I only need it because BusinessSite, like LifelineSite, does not have a Zone. Instead I can add a no-arg constructor to Site, and remove the no-arg constructor from LifelineSite.

```
Class Site
 Site() {}
```

This does not affect ResidentialSite or DisabilitySite for they have their own constructors. They cannot use the no-arg constructor unless I was to add one.

BusinessSite also has a variation on addReading and how the reading are obtained.

```
Class BusinessSite
 public void addReading(Reading newReading) {
    _readings[++lastReading] = newReading;
 }
 public Dollars charge() {
    int usage = _readings[lastReading].amount() - _readings[lastReading -1].amount();
    return charge(usage);
 }
```

So my first move, as with LifelineSite is to remove addReading, change charge, and run the tests to see if all still works.

```
public Dollars charge() {
```

```
      int usage = lastReading().amount() - previousReading().amount();
      return charge(usage);
   }
```

Indeed it did.

Now it's time to look at the one argument charge method, and to see if we can break it down into the usual four items to sum. Currently charge looks like this

```
 private  Dollars charge(int usage) {
     Dollars result;

     if (usage == 0) return new Dollars(0);

   double t1 = START_RATE - ((END_RATE * END_AMOUNT) - START_RATE) / (END_AMOUNT - 1);
   double t2 = ((END_RATE * END_AMOUNT) - START_RATE) * Math.min(END_AMOUNT, usage) /
(END_AMOUNT - 1);
   double t3 = Math.max(usage - END_AMOUNT, 0) * END_RATE;

   result = new Dollars (t1 + t2 + t3);

   // fuel charge
   result = result.plus(new Dollars (usage * 0.0175));

   // add in the taxes
   Dollars base = new Dollars (result.min(new Dollars (50)).times(0.07));
      if (result.isGreaterThan(new Dollars (50))) {
         base = new Dollars (base.plus(result.min(new Dollars(75)).minus(new
Dollars(50)).times(0.06)));
      };
      if (result.isGreaterThan(new Dollars (75))) {
         base = new Dollars (base.plus(result.minus(new Dollars(75)).times(0.05)));
      };
   result = result.plus(base);
   return result;

      }
```

The situation is slightly different. This time we have a base charge, a fuel charge, but a combined taxes method that does an algorithm on the combined amount. This method will not fit our current template method. But it may be possible to alter the template method to make it all fit. Our first task is to decompose this method to make it more palatable. We can begin by extracting the fuel charge.

```
 private  Dollars charge(int usage) {
     Dollars result;

     if (usage == 0) return new Dollars(0);

   double t1 = START_RATE - ((END_RATE * END_AMOUNT) - START_RATE) / (END_AMOUNT - 1);
   double t2 = ((END_RATE * END_AMOUNT) - START_RATE) * Math.min(END_AMOUNT, usage) /
(END_AMOUNT - 1);
   double t3 = Math.max(usage - END_AMOUNT, 0) * END_RATE;

   result = new Dollars (t1 + t2 + t3);

   //add the fuel charge
   result = result.plus(fuelCharge());

   // add the taxes
   Dollars base = new Dollars (result.min(new Dollars (50)).times(0.07));
      if (result.isGreaterThan(new Dollars (50))) {
         base = new Dollars (base.plus(result.min(new Dollars(75)).minus(new
Dollars(50)).times(0.06)));
      };
      if (result.isGreaterThan(new Dollars (75))) {
         base = new Dollars (base.plus(result.minus(new Dollars(75)).times(0.05)));
      };
   result = result.plus(base);
   return result;

      }
```

We can then extract the baseCharge.

```
   private  Dollars charge(int usage) {
      Dollars result = baseCharge();
      result = result.plus(fuelCharge());

      // add the taxes
```

```
    Dollars base = new Dollars (result.min(new Dollars (50)).times(0.07));
       if (result.isGreaterThan(new Dollars (50))) {
         base = new Dollars (base.plus(result.min(new Dollars(75)).minus(new
Dollars(50)).times(0.06)));
       };
       if (result.isGreaterThan(new Dollars (75))) {
         base = new Dollars (base.plus(result.minus(new Dollars(75)).times(0.05)));
       };
    result = result.plus(base);
    return result;

  }

  public Dollars baseCharge() {
    if (lastUsage() == 0) return new Dollars(0);
    double t1 = START_RATE - ((END_RATE * END_AMOUNT) - START_RATE) / (END_AMOUNT - 1);
    double t2 = ((END_RATE * END_AMOUNT) - START_RATE) *
         Math.min(END_AMOUNT, lastUsage()) / (END_AMOUNT - 1);
    double t3 = Math.max(lastUsage() - END_AMOUNT, 0) * END_RATE;
    return new Dollars (t1 + t2 + t3);
   }
```

And then the taxes

```
  private  Dollars charge(int usage) {
    Dollars result = baseCharge();
    result = result.plus(fuelCharge());
    result = result.plus(taxes());
    return result;
  }
  protected Dollars taxes() {
    Dollars taxable = baseCharge().plus(fuelCharge());
    Dollars result = new Dollars (taxable.min(new Dollars (50)).times(0.07));
    if (taxable.isGreaterThan(new Dollars (50))) {
       result = new Dollars (result.plus(taxable.min(new Dollars(75)).minus(
           new Dollars(50)).times(0.06)));

    };
    if (taxable.isGreaterThan(new Dollars (75))) {
       result = new Dollars (result.plus(taxable.minus(new Dollars(75)).times(0.05)));
    };
    return result;
  }
```

We can now alter the template method to work with this site. First I change the name of the current taxes method in Site to baseTaxes. When I do this I need to first look to see if any subclass implements taxes. I can do that with a global search. LifelineSite does this so I rename taxes in both Site and LifelineSite. Next I need to check which methods call taxes. I can do this by either a text search or by compiling. The compiler tells me that only charge calls taxes. I can now make the changes I want to Site and test.

```
Class Site
  public Dollars charge() {
    return baseCharge().plus(fuelCharge()).plus(taxes());
  }

  protected Dollars taxes() {
    return baseTaxes().plus(fuelChargeTaxes());
  }
```

Now Site's template method is in the right form, I can remove the charge methods on BusinessSite.

A Second Attempt to Build a Rate Table

The method for taxes has a very familiar form.

```
  protected Dollars taxes() {
    Dollars taxable = baseCharge().plus(fuelCharge());
    Dollars result = new Dollars (taxable.min(new Dollars (50)).times(0.07));
    if (taxable.isGreaterThan(new Dollars (50))) {
       result = new Dollars (result.plus(taxable.min(new Dollars(75)).minus(new
Dollars(50)).times(0.06)));

    };
    if (taxable.isGreaterThan(new Dollars (75))) {
       result = new Dollars (result.plus(taxable.minus(new Dollars(75)).times(0.05)));
    };
    return result;
```

```
}
```

The form is exactly the same as that for Lifeline's site's base charge. This makes me want to revisit the RateTable class, since I will now have two places to use it. First I can it plug into BusinessSite.taxes and test.

```
class BusinessSite
  protected Dollars taxes() {
     Dollars taxable = baseCharge().plus(fuelCharge());
     double [] table = {     0.07, 50,
                             0.06, 75,
                             0.05};
     return new Dollars (new RateTable(table).value(taxable.amount()));
  }
```

I can do some extraction to make that clearer.

```
  protected Dollars taxes() {
     return new Dollars (taxTable().value(taxable().amount()));
  }

  protected Dollars taxable () {
     return baseCharge().plus(fuelCharge());
  }

  protected RateTable taxTable() {
     double [] table = {     0.07, 50,
                             0.06, 75,
                             0.05};
     return new RateTable (table);
  }
```

I will do the same for LifelineSite

```
  protected Dollars baseCharge() {
     return new Dollars (baseChargeTable().value(lastUsage()));
  }

  protected RateTable baseChargeTable() {
     double [] table = {     0.03, 100,
                 0.05, 200,
                 0.07};
     return new RateTable (table);
  }
```

Now I'm going to actually use RateTable I want to refactor its code to make it easier to understand. The main bit that concerns me is the constructor.

```
  public RateTable(double[] arg) {
     int arrayLengths = arg.length / 2 + 1;
     _rates = new double[arrayLengths];
     _limits = new int[arrayLengths];
     int argIndex = 0;
     for (int i = 0; i < (arrayLengths - 1); i++) {
        _rates[i] = arg[argIndex++];
        _limits[i] = (int) arg[argIndex++];
     };
     _rates[arrayLengths - 1] = arg [arg.length -1];
     _limits[arrayLengths - 1] = Integer.MAX_VALUE;
  }
```

Using vectors seems like it would simplify things a lot, but Vectors must contain objects, not reals or ints, so we would have a lot of downcasting and conversion in the value method. For the moment nothing really occurs to me that I can do to it, so I will let it be.

Refactoring BusinessSite.baseCharge

Another awkward looking method is BusinessSite's baseCharge.

```
  protected Dollars baseCharge() {
     if (lastUsage() == 0) return new Dollars(0);
     double t1 = START_RATE - ((END_RATE * END_AMOUNT) - START_RATE) / (END_AMOUNT - 1);
     double t2 = ((END_RATE * END_AMOUNT) - START_RATE) *
        Math.min(END_AMOUNT, lastUsage()) / (END_AMOUNT - 1);
     double t3 = Math.max(lastUsage() - END_AMOUNT, 0) * END_RATE;
     return new Dollars (t1 + t2 + t3);
  }
```

I can refactor this by first looking at the way the lastUsage is used. One part, up to the END_AMOUNT is multiplied by a factor to make t2. That part over END_AMOUNT is multiplied by the END_RATE. I can thus divide the lastUsage into its two parts with methods.

```
protected Dollars baseCharge() {
   if (lastUsage() == 0) return new Dollars(0);
   double t1 = START_RATE - ((END_RATE * END_AMOUNT) - START_RATE) / (END_AMOUNT - 1);
   double t2 = ((END_RATE * END_AMOUNT) - START_RATE) *
        usageBelowLimit() / (END_AMOUNT - 1);
   double t3 = usageAboveLimit() * END_RATE;
   return new Dollars (t1 + t2 + t3);
}

protected int usageAboveLimit () {
   return Math.max(lastUsage() - END_AMOUNT, 0);
}

protected int usageBelowLimit() {
   return Math.min(END_AMOUNT, lastUsage());
}
```

The usageBelowLimit is being multiplied by a static factor that is calculated from the current static contsants. I can factor this out.

```
protected Dollars baseCharge() {
   if (lastUsage() == 0) return new Dollars(0);
   double t1 = START_RATE - belowLimitRate();
   double t2 = usageBelowLimit() * belowLimitRate();
   double t3 = usageAboveLimit() * END_RATE;
   return new Dollars (t1 + t2 + t3);
}

protected static double belowLimitRate() {
   return ((END_RATE * END_AMOUNT) - START_RATE) / (END_AMOUNT - 1);
}
```

Finally I can rename the temps to something that better reflects my understanding of their use

```
protected Dollars baseCharge() {
   if (lastUsage() == 0) return new Dollars(0);
   double constant = START_RATE - belowLimitRate();
   double chargeBelowLimit = usageBelowLimit() * belowLimitRate();
   double chargeAboveLimit = usageAboveLimit() * END_RATE;
   return new Dollars (constant + chargeBelowLimit + chargeAboveLimit);
}
```

TK add a new requirement of generating a history of charges, and show how refactoring first makes it easier to do.

TK start with a single site class and refactor in the other direction