Circular Buffer (Lab 10)

The Problem
We are going to work on making our own classes with private data members and special accessors. We are going to build a CircularBuffer class, a common data structure with well known accessors.

Some Background
Our CircularBuffer will be a data structure that stores long. A CircularBuffer is a fixed size FIFO (First In, First Out) data structure. It is essentially a line (a queue). First thing added (the Head position in the diagram) is the first thing read. The next thing added is at the Tail position. It is the last thing added, the last thing that will be read. The underlying data structure for this approach has a fixed size data structure. It can become empty, it can become full. It does not grow or shrink in size over the course of the run of the program.

![Circular Buffer Diagram]

Things you can do with your CircularBuffer:
- you can add to the CircularBuffer. An element is added at the Tail position. The write position is then advanced (clockwise in the diagram)
- you can remove an element. The element at the Head position is removed. The Head position is then advanced (clockwise in the diagram)
- you can test if it is full
- you can test if it is empty.
- you can report the front element
- you can report the back element

Your Tasks
We are going to make a CircBuf class with these characteristics and test it, using a Visual Studio Project

The Class
The CircBuff class will have an underlying data member buf_ of type vector<long> of fixed size. This is a private data member, which will represent the underlying data array. buf_ is private, you cannot access it from a main program using the class.
Data Members

- int sz_ (the maximum size of the fixed size buffer)
- int cnt_ (the number of active elements in the buffer)
- size_t head_ (an index to the element that will be read by front())
- size_t tail_ (an index to where the next element will be written, where add() will put the next element)
- buf_, a vector<long>, the data being stored.

Function Members

- CircBuf constructor, one argument, the fixed size buffer of long
  - takes a default of 10, thus allowing for a default constructor.
- CircBuf constructor:
  - two args: an initialization_list<long> and a buffer size
    - if the parameter size is smaller than initialization list, throw a runtime_error
  - if successful, initializes the underlying vector to the provided parameter size and copies the values of the initializer_list into that vector
- long front() const member function, no parameters
  - if CircBuf is not empty, returns the long indexed by head_
  - if the CircBuf is empty, throws a runtime_error
- long back() const member function, no parameters
  - if CircBuf is not empty, returns the last long (tail_-1). 
  - if the CircBuf is empty, throws a runtime_error
- void remove() member function, no parameters
  - if CircBuf is not empty, advances head_ by one.
  - if the CircBuf is empty, throws runtime_error
- void add(long) member function, single long parameter
  - if CircBuf is not full, places the parameter in buf_ at the index indicated by tail_, advances tail_ by one with wrap around as described
  - if CircBuf is full, throws a runtime_error
- bool empty() const member function, no parameters
  - returns true if the CircBuf is empty, false otherwise.
- bool full() const member function, no parameters.
  - returns true if the CircBuf is full, false otherwise.

Friends

- ostream& operator<<(ostream &out, const CircBuf &cb). This is a friend function (not a member). It prints the values at the front and back of the buffer (what is indexed by head_ and one back from tail_), the cnt_ of elements in the buffer and the underlying buffer array
  - if the buffer is empty, prints a message "CircBuf empty"
Implementation, circbuf.cpp
The most important thing to note is the circular nature of the buffer as implemented in a vector. The two indicies: front_ (where elements are read from) and back_ (where elements are added). They can wrap around the buffer like we have done with clock arithmetic:

- if back_ goes past the last index of the data structure, it "wraps around" to the first index using the modulus operator (%) based on the fixed buffer size
- the same is true for front_
- in this way you can keep reusing the underlying buffer.

<table>
<thead>
<tr>
<th>head_ = 0</th>
<th>tail_ = 0</th>
<th>cnt_ = 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 0 0 0 0</td>
<td>0 1 2 3</td>
<td></td>
</tr>
</tbody>
</table>

Initial situation

<table>
<thead>
<tr>
<th>head_ = 0</th>
<th>tail_ = 2</th>
<th>cnt_ = 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 8 0 0</td>
<td>0 1 2 3</td>
<td></td>
</tr>
</tbody>
</table>

cb.add(7) cb.add(8)
remember, tail_ is where the next add will put an element

<table>
<thead>
<tr>
<th>head_ = 2</th>
<th>tail_ = 2</th>
<th>cnt_ = 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 8 0 0</td>
<td>0 1 2 3</td>
<td></td>
</tr>
</tbody>
</table>

cb.remove()
Nothing is erased, just ignored!

<table>
<thead>
<tr>
<th>head_ = 2</th>
<th>tail_ = 1</th>
<th>cnt_ = 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 8 4 5</td>
<td>0 1 2 3</td>
<td></td>
</tr>
</tbody>
</table>

cb.add(4) cb.add(5) cb.add(6)
note value 8 at indx 1 is still there even though it was removed. Next add will overwrite it.

<table>
<thead>
<tr>
<th>head_ = 0</th>
<th>tail_ = 1</th>
<th>cnt_ = 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 8 4 5</td>
<td>0 1 2 3</td>
<td></td>
</tr>
</tbody>
</table>

cb.remove() cb.remove()

Notes
- head_ == tail_ in two situations: full and empty. How to differentiate full from empty?
- You have to be careful with a vector in this case. The vector will grow under a push_back but you want this buffer to be of a fixed size. How to deal with that?

Test
You are given lab10_circbuf.h. Implement lab10_circbuff.cpp locally in Visual Studio and then run the tests on Mimir
Extra
For those that find the above relatively straight forward to do, try the follow extra work:

• it might seem a little odd, but you could overload the + operator to place the next element in the buffer (a different way to do add). It would have to allow statements like the following.

```c
    cb = cb + 5;
    cb = 5 + cb;
```

In this case, the operator would make a new CircBuf, with the element added to the end. Thus this would be the addition of a CircBuf and a long.

What to do for the fixed size of the newly made CircBuf? You could make the new buffer a straight copy of cb and throw an error if it exceeds the size. If not big enough, you could also make it one bigger. Which would be better?

Uncomment the appropriate parts in lab10_circbuf.h and implement. No tests in Mimir, you're on your own here.

• if you are really bored, you could create the addition of two CircBuf. It would take the two contents and combine them. **Order here would be important** (contents of the lhs first followed by the rhs).

```c
    cb = cb + another_buff  // cb contents first, another_buf second
    cb = another_buf + cb    // another_buf contents first, cb second
```

Again, what to do with the fixed size of the returned buffer? This is a tougher call. It seems likely that the combined buffers could be too big (bigger than either of the two argument CircBufs). Should we throw an error or make the new CircBuf big enough to hold the result? Interesting problem.

Again, uncomment the appropriate part of lab10_circbuf.h and implement. Again, no tests in Mimir.

See, class design can be lots of fun!?