// stack1.cpp

```cpp
#include <iostream>
#include <string>
#include <stack>
using namespace std;

int main()
{

    stack<string> stringStack;  // stack is LIFO

       string myString="first string";
       string myString2="second String";

       cout << myString << endl;
       cout << myString2 << endl;

       stringStack.push(myString);
       stringStack.push(myString2);

       string outputString = stringStack.top();
       stringStack.pop();
       cout << "popped value is " << outputString << endl;

    outputString = stringStack.top();
       stringStack.pop();
       cout << "popped value is " << outputString << endl;

       return 0;
}
```

output

```
first string
second String
popped value is second String
popped value is first string
```

// stack2.cpp

```cpp
#ifndef H_StackType
#define H_StackType

template <class Type>
class stackType
{
public:
    bool isEmptyStack();
         //Function returns true if the stack is empty;
         //otherwise, it returns false.
    bool isFullStack();
         //Function returns true if the stack is full;
         //otherwise, it returns false.
    void destroyStack();
         //Remove all elements from the stack
         //Post: top = 0
```

```
    void push(const Type& newItem);
        //Add the newItem to the stack
        //Post: stack is changed and the newItem
        //     is added to the top of stack
    void pop(Type& poppedItem);
        //Remove the top element of the stack
        //Post: Stack is changed and the top element
        //     is removed from the stack. The top element
        //     of the stack is saved in poppedItem.
    stackType(int stackSize = 100);
        //constructor
        //Create an array of size stackSize to hold the
        // stack elements. The default stack size is 100
        //Post: The variable list contains the base
        //     address of the array, top = 0 and
        //     maxStackSize = stackSize
    stackType(const stackType<Type>& otherStack);
        //copy constructor
    ~stackType();
        //destructor
        //Remove all elements from the stack
        //Post: The array (list) holding the stack
        //     elements is deleted

private:
    int maxStackSize;     //variable to store the maximum stack size
    int top;              //variable to point to the top of the stack
    Type *list;       //pointer to the array that holds
                                //the stack elements
};

#include <iostream>
using namespace std;

template<class Type>
void stackType<Type>::destroyStack()
{
      top = 0;
}//end destroyStack

template<class Type>
bool stackType<Type>::isEmptyStack()
{
      return(top == 0);
}//end isEmptyStack

template<class Type>
bool stackType<Type>::isFullStack()
{
      return(top == maxStackSize);
} //end isFullStack

template<class Type>
stackType<Type>::stackType(int stackSize)
{
```

```
	if(stackSize <= 0)
	{
		cout<<"Size of the array to hold the stack must "
	    <<"be positive."<<endl;
		cout<<"Creating an array of size 100."<<endl;

		maxStackSize = 100;
	}
	else
		maxStackSize = stackSize; //set the stack size to
		                                    //the value specified by
		                                    //the parameter stackSize

	top = 0;                                    //set top to 0
	list = new Type[maxStackSize];   //create the array to
		                                          //hold the stack elements
}//end constructor


template<class Type>
stackType<Type>::~stackType() //destructor
{
   delete [] list; //deallocate memory occupied by the array
}//end destructor

template<class Type>
void stackType<Type>::push(const Type& newItem)
{
	list[top] = newItem; //add newItem at the top of the stack
	top++;   // increment the top
}//end push

template<class Type>
void stackType<Type>::pop(Type& poppedItem)
{
	top--;                      //decrement the top
	poppedItem = list[top];     //copy the top element of
		                                    //the stack into poppedItem
	cout << "Popped item is " << poppedItem << endl;
}//end pop

#endif
// another array implementation.cpp
//Program to test the various operations of a stack

#include <iostream>
using namespace std;

int main()
{
	stackType<int> stack(50);
	int poppedInt;
	stack.push(23);
	stack.push(45);
	stack.push(38);
```

```
    stack.pop(poppedInt);
    stack.pop(poppedInt);
    stack.pop(poppedInt);


       stackType<float> floatStack;      // floatStack is object of class
Stack<float>
       float poppedFloat;
    floatStack.push(1111.1);      // push 3 floats, pop 3 floats
    floatStack.push(2222.2);
    floatStack.push(3333.3);
    floatStack.pop(poppedFloat);
    floatStack.pop(poppedFloat);
    floatStack.pop(poppedFloat);

    stackType<long> longStack;       // longStack is object of class Stack<long>
       long poppedLong;
    longStack.push(123123123L);  // push 3 longs, pop 3 longs
    longStack.push(234234234L);
    longStack.push(345345345L);
    longStack.pop(poppedLong);
    longStack.pop(poppedLong);
    longStack.pop(poppedLong);
}
```

Output

```
Popped item is 38
Popped item is 45
Popped item is 23
Popped item is 3333.3
Popped item is 2222.2
Popped item is 1111.1
Popped item is 345345345
Popped item is 234234234
Popped item is 123123123
```

// stack3.cpp

```
#ifndef H_StackType
#define H_StackType

#include <iostream>

using namespace std;

//Definition of the node
template <class Type>
struct nodeType
{
       Type info;
```

```
      nodeType<Type> *link;
};

template<class Type>
class linkedStackType
{
public:
    const linkedStackType<Type>& operator=
                                (const linkedStackType<Type>&);
        //overload the assignment operator
    void initializeStack();
        //Initialize the stack to an empty state.
        //Post condition: Stack elements are removed; top = NULL
    bool isEmptyStack();
        //Function returns true if the stack is empty;
        //otherwise, it returns false
    bool isFullStack();
        //Function returns true if the stack is full;
        //otherwise, it returns false
    void push(const Type& newItem);
        //Add the newItem to the stack.
        //Pre condition: stack exists and is not full
        //Post condition: stack is changed and the newItem
        //     is added to the top of stack. top points to
        //     the updated stack
    void pop(Type& poppedElement);
        //Remove the top element of the stack.
        //Pre condition: Stack exists and is not empty
        //Post condition: stack is changed and the top
        //    element is removed from the stack. The top
        //    element of the stack is saved in poppedElement
    void destroyStack();
        //Remove all elements of the stack, leaving the
        //stack in an empty state.
        //Post condition: top = NULL
    linkedStackType();
        //default constructor
        //Post condition: top = NULL
    linkedStackType(const linkedStackType<Type>& otherStack);
        //copy constructor
    ~linkedStackType();
        //destructor
        //All elements of the stack are removed from the stack

private:
    nodeType<Type> *top; // pointer to the stack
};


template<class Type> //default constructor
linkedStackType<Type>::linkedStackType()
{
      top = NULL;
}
```

```cpp
template<class Type>
void linkedStackType<Type>::destroyStack()
{
      nodeType<Type> *temp; //pointer to delete the node

      while(top != NULL)  //while there are elements in the stack
      {
         temp = top;       //set temp to point to the current node
         top = top->link; //advance top to the next node
         delete temp;     //deallocate memory occupied by temp
      }
}// end destroyStack



template<class Type>
void linkedStackType<Type>:: initializeStack()
{
    destroyStack();
}

template<class Type>
bool linkedStackType<Type>::isEmptyStack()
{
      return(top == NULL);
}

template<class Type>
bool linkedStackType<Type>:: isFullStack()
{
   return 0;
}

template<class Type>
void linkedStackType<Type>::push(const Type& newElement)
{
      nodeType<Type> *newNode; //pointer to create the new node

      newNode = new nodeType<Type>; //create the node
      newNode->info = newElement;   //store newElement in the node
      newNode->link = top;          //insert newNode before top
      top = newNode;             //set top to point to the top node
} //end push


template<class Type>
void linkedStackType<Type>::pop(Type& poppedElement)
{
   nodeType<Type> *temp;         //pointer to deallocate memory

   poppedElement = top->info;    //copy the top element into
                                             //poppedElement
   cout << "Popped item is " << poppedElement << endl;
   temp = top;                               //set temp to point to the top node
   top = top->link;                    //advance top to the next node
```

```
   delete temp;                               //delete the top node
}//end pop


template<class Type>   //copy constructor
linkedStackType<Type>::linkedStackType(const linkedStackType<Type>& otherStack)
{
	nodeType<Type> *newNode, *current, *last;

	if(otherStack.top == NULL)
		top = NULL;
	else
	{
		current = otherStack.top; //set current to point to the
		                                      //stack to be copied

			//copy the top element of the stack
		top = new nodeType<Type>;   //create the node
		top->info = current->info;  //copy the info
		top->link = NULL;             //set the link field of the
		                                      //node to null
		last = top;                 //set last to point to the node
		current = current->link;    //set current to point to the
		                                 //next node

			//copy the remaining stack
		while(current != NULL)
		{
			newNode = new nodeType<Type>;
			newNode->info = current->info;
			newNode->link = NULL;
			last->link = newNode;
			last = newNode;
			current = current->link;
		}//end while
	}//end else
}//end copy constructor


template<class Type> //destructor
linkedStackType<Type>::~linkedStackType()
{
	nodeType<Type> *temp;

	while(top != NULL)     //while there are elements in the stack
	{
		temp = top;        //set temp to point to the current node
		top = top ->link;  //advance first to the next node
		delete temp;       //deallocate the memory occupied by temp
	}//end while
}//end destructor

template<class Type>   //overloading the assignment operator
const linkedStackType<Type>& linkedStackType<Type>::operator=
```

```
                      (const linkedStackType<Type>& otherStack)
{
      nodeType<Type> *newNode, *current, *last;

      if(this != &otherStack) //avoid self-copy
      {
            if(top != NULL)  //if the stack is not empty, destroy it
                  destroyStack();

            if(otherStack.top == NULL)
                  top = NULL;
            else
            {
                  current = otherStack.top; //set current to point to
                                                      //the stack to be
copied

                        //copy the top element of otherStack
                  top = new nodeType<Type>; //create the node
                  top->info = current->info;//copy the info
                  top->link = NULL;               //set the link field of the
                                                      //node to null
                  last = top;                     //make last point to the node
                  current = current->link;  //make current point to
                                                //the next node

                        //copy the remaining elements of the stack
                  while(current != NULL)
                  {
                        newNode = new nodeType<Type>;
                        newNode->info = current->info;
                        newNode->link = NULL;
                        last->link = newNode;
                        last = newNode;
                        current = current->link;
                  }//end while
            }//end else
      }//end if

      return *this;
}//end operator=
#endif
//linkstack.cpp
//This program tests the various operations of a linked stack

#include <iostream>


using namespace std;

void testCopy(linkedStackType<int> OStack);

int main()
{
      linkedStackType<int> stack;
```

```
	linkedStackType<int> otherStack;
	linkedStackType<int> newStack;
	int num;

	stack.push(34);
	stack.push(43);
	stack.push(27);
	newStack = stack;

	cout<<"After the assignment operator, newStack: "<<endl;

	while(!newStack.isEmptyStack())
	{
		newStack.pop(num);
		cout<<num<<endl;
	}

	otherStack = stack;

	cout<<"Testing the copy constructor"<<endl;

	testCopy(otherStack);

	cout<<"After the copy constructor, otherStack: "<<endl;

	while(!otherStack.isEmptyStack())
	{
		otherStack.pop(num);
		cout<<num<<endl;
	}

	linkedStackType<int> intStack;
	int poppedInt;
	intStack.push(23);
	intStack.push(45);
	intStack.push(38);

    intStack.pop(poppedInt);
    intStack.pop(poppedInt);
    intStack.pop(poppedInt);


	linkedStackType<float> floatStack;	// floatStack is object of class
Stack<float>
	float poppedFloat;
    floatStack.push(1111.1);	// push 3 floats, pop 3 floats
    floatStack.push(2222.2);
    floatStack.push(3333.3);
    floatStack.pop(poppedFloat);
    floatStack.pop(poppedFloat);
    floatStack.pop(poppedFloat);

    linkedStackType<long> longStack;	// longStack is object of class
Stack<long>
	long poppedLong;
```

```
    longStack.push(123123123L);  // push 3 longs, pop 3 longs
    longStack.push(234234234L);
    longStack.push(345345345L);
    longStack.pop(poppedLong);
    longStack.pop(poppedLong);
    longStack.pop(poppedLong);

	return 0;
}

void testCopy(linkedStackType<int> OStack) //function to test the
                                                                     // copy
constructor
{
	int num;

	cout<<"Stack in the function testCopy:"<<endl;

	while(!OStack.isEmptyStack())
	{
		OStack.pop(num);
		cout<<num<<endl;
	}
}
```

output

```
After the assignment operator, newStack:
Popped item is 27
27
Popped item is 43
43
Popped item is 34
34
Testing the copy constructor
Stack in the function testCopy:
Popped item is 27
27
Popped item is 43
43
Popped item is 34
34
After the copy constructor, otherStack:
Popped item is 27
27
Popped item is 43
43
Popped item is 34
34
Popped item is 38
Popped item is 45
Popped item is 23
Popped item is 3333.3
Popped item is 2222.2
Popped item is 1111.1
Popped item is 345345345
Popped item is 234234234
```

```
Popped item is 123123123
```

//5.12

```
vector<string> getHtmlTags() {             // store tags in a vector
  vector<string> tags;                     // vector of html tags
  while (cin) {                            // read until end of file
    string line;
    getline(cin, line);                    // input a full line of text
    int pos = 0;                           // current scan position
    int ts = line.find("<", pos);          // possible tag start
    while (ts != string::npos) {           // repeat until end of string
      int te = line.find(">", ts+1);       // scan for tag end
      tags.push_back(line.substr(ts, te-ts+1)); // append tag to the vector
      pos = te + 1;                              // advance our position
      ts = line.find("<", pos);
    }
  }
  return tags;                             // return vector of tags
 }
```

//5.13

```
  bool isHtmlMatched(const vector<string>& tags) {
  LinkedStack S;                                 // stack for opening tags
  typedef vector<string>::const_iterator Iter;// iterator
type                                             // iterate through vector
  for (Iter p = tags.begin(); p != tags.end(); ++p) {
    if (p->at(1) != '/')                   // opening tag?
      S.push(*p);                          // push it on the stack
    else {                                       // else must be closing tag
      if (S.empty()) return false;         // nothing to match - failure
      string open = S.top().substr(1);     // opening tag excluding '<'
      string close = p->substr(2);         // closing tag excluding '</'
      if (open.compare(close) != 0) return false; // fail to match
          else S.pop();                          // pop matched element
```

```
    }
   }
   if (S.empty()) return true;                        // everything matched - good
   else return false;                                 // some unmatched - bad
  }
```

//5.14

```
int main() {                                          // main HTML tester
   if (isHtmlMatched(getHtmlTags()))                  // get tags and test them
     cout << "The input file is a matched HTML document." << endl;
   else
     cout << "The input file is not a matched HTML document." << endl;
  }
```

//queue1.h

```
// queue::push/pop
#include <iostream>       // std::cin, std::cout
#include <queue>          // std::queue

int main ()
{
  std::queue<int> myqueue;
  int myint;

  std::cout << "Please enter some integers (enter 0 to end):\n";

  do {
    std::cin >> myint;
    myqueue.push (myint);
  } while (myint);

  std::cout << "myqueue contains: ";
  while (!myqueue.empty())
  {
    std::cout << ' ' << myqueue.front();
    myqueue.pop();
  }
  std::cout << '\n';

  return 0;
}
```

Output

```
Please enter some integers (enter 0 to end):
4
7
8
3
0
myqueue contains:  4 7 8 3 0
```

//queue2.h

```
//queue2.h

#ifndef H_QueueAsArray
#define H_QueueAsArray

#include <iostream>

using namespace std;

template<class Type>
class queueType
{
public:
    const queueType<Type>& operator=(const queueType<Type>&);
                // overload the assignment operator
       void initializeQueue();
       void destroyQueue();
       int isEmptyQueue();
       int isFullQueue();
       void addQueue(Type queueElement);
       void deQueue(Type& deqElement);

       queueType(int queueSize = 100);
       queueType(const queueType<Type>& otherQueue);
              // copy constructor
       ~queueType();
              //destructor

private:
       int maxQueueSize;
       int count;
       int front;
       int rear;
       Type *list;  //pointer to the array that holds the queue elements
};

template<class Type>
void queueType<Type>::initializeQueue()
{
       front = 0;
    rear = maxQueueSize - 1;
       count = 0;
}

template<class Type>
void queueType<Type>::destroyQueue()
{
       front = 0;
    rear = maxQueueSize - 1;
       count = 0;
}
```

```
template<class Type>
int queueType<Type>::isEmptyQueue()
{
   return(count == 0);
}

template<class Type>
int queueType<Type>::isFullQueue()
{
   return(count == maxQueueSize);
}

template<class Type>
void queueType<Type>::addQueue(Type newElement)
{
   rear = (rear + 1) % maxQueueSize; // use mod operator to advance rear
                                                         //because array is
circular
   count++;
   list[rear] = newElement;
}

template<class Type>
void queueType<Type>::deQueue(Type& deqElement)
{
   deqElement = list[front];

   count--;
   front = (front + 1) % maxQueueSize; // use mod operator to advance
                                              // rear because the array is
circular

}


template<class Type>
queueType<Type>::queueType(int queueSize)   //constructor
{
       if(queueSize <= 0)
       {
              cout<<"Size of the array to hold the queue must "
                     <<"be positive."<<endl;
              cout<<"Creating an array of size 100."<<endl;

              maxQueueSize = 100;
       }
       else
              maxQueueSize = queueSize;  //set maxQueueSize to queueSize

       front = 0;      //initialize front
       rear = maxQueueSize - 1;     //initiaize rear
       count = 0;
       list = new Type[maxQueueSize];  //create the array to
                              //hold queue elements
}
```

```
template<class Type>
queueType<Type>::~queueType()   //destructor
{
   delete [] list;
}

template<class Type>
const queueType<Type>& queueType<Type>::operator=
                          (const queueType<Type>& otherQueue)
{
       cout<<"Write the definition of the function "
              <<"to overload the assignment operator"<<endl;
}


#endif
//queue1.cpp
//Test Program Queue as Array

#include <iostream>


using namespace std;

int main()
{
       queueType<int> queue;
       int x, y;

       queue.initializeQueue();
       x = 4;
       y = 5;
       queue.addQueue(x);
       queue.addQueue(y);
       queue.deQueue(x);
       queue.addQueue(x + 5);
       queue.addQueue(16);
       queue.addQueue(x);
       queue.addQueue(y - 3);

       cout<<"Queue Elements: ";

       while(!queue.isEmptyQueue())
       {
              queue.deQueue(y);
              cout<<" "<<y;
       }
       cout<<endl;

       return 0;
}
```

output

Queue Elements: 5 9 16 4 2

//5.18

```
typedef string Elem;                    // queue element type
  class LinkedQueue {                   // queue as doubly linked list
  public:
    LinkedQueue();                 // constructor
    int size() const;              // number of items in the queue
    bool empty() const;                 // is the queue empty?
    const Elem& front() const throw(QueueEmpty); // the front element
    void enqueue(const Elem& e);   // enqueue element at rear
    void dequeue() throw(QueueEmpty);   // dequeue element at front
  private:                         // member data
    CircleList C;                  // circular list of elements
    int n;                         // number of elements
  };
```

//5.19

```
LinkedQueue::LinkedQueue()              // constructor
    : C(), n(0) { }

  int LinkedQueue::size() const         // number of items in the queue
    { return n; }

  bool LinkedQueue::empty() const       // is the queue empty?
    { return n == 0; }
                                   // get the front element
  const Elem& LinkedQueue::front() const throw(QueueEmpty) {
    if (empty())
      throw QueueEmpty("front of empty queue");
    return C.front();              // list front is queue front
```

```
 }
```

//5.20

```
void LinkedQueue::enqueue(const Elem& e) {
   C.add(e);                              // insert after cursor
   C.advance();                           // ...and advance
   n++;
 }
                                          // dequeue element at front
 void LinkedQueue::dequeue() throw(QueueEmpty) {
   if (empty())
     throw QueueEmpty("dequeue of empty queue");
   C.remove();                                   // remove from list front
   n--;
 }
```

//queue3.h

```
#ifndef H_linkedQueue
#define H_linkedQueue

#include <iostream>

using namespace std;

//Definition of the node
template <class Type>
struct nodeType
{
	Type info;
	nodeType<Type> *link;
};

template<class Type>
class linkedQueueType
{
public:
    const linkedQueueType<Type>& operator=
                                                    (const linkedQueueType<Type>&);
              // overload the assignment operator
    bool isEmptyQueue();
    bool isFullQueue();
    void destroyQueue();
    void initializeQueue();
    void addQueue(const Type& newElement);
    void deQueue(Type& deqElement);
```

```
    linkedQueueType (); //default constructor
    linkedQueueType(const linkedQueueType<Type>& otherQueue);
             //copy constructor
    ~linkedQueueType(); //destructor

private:
    nodeType<Type> *front; //pointer to the front of the queue
    nodeType<Type> *rear;  //pointer to the rear of the queue
};


template<class Type>
linkedQueueType<Type>::linkedQueueType() //default constructor
{
       front = NULL; // set front to null
       rear = NULL;  // set rear to null
}


template<class Type>
bool linkedQueueType<Type>::isEmptyQueue()
{
       return(front == NULL);
}

template<class Type>
bool linkedQueueType<Type>::isFullQueue()
{
       return false;
}

template<class Type>
void linkedQueueType<Type>::destroyQueue()
{
       nodeType<Type> *temp;

       while(front != NULL)  //while there are elements left in the queue
       {
          temp = front;          // set temp to point to the current node
          front = front ->link; // advance front to the next node
          delete temp;           // deallocate memory occupied by temp
       }

       rear = NULL;  // set rear to null
}

template<class Type>
void linkedQueueType<Type>::initializeQueue()
{
  destroyQueue();
}

template<class Type>
void linkedQueueType<Type>::addQueue(const Type& newElement)
{
```

```
      nodeType<Type> *newNode;

      newNode = new nodeType<Type>;    //create the node
      newNode->info = newElement;             //store the info
    newNode->link = NULL;              //initialize the link field to null

    if(front == NULL)                         //if initially queue is empty
    {
            front = newNode;
            rear = newNode;
    }
    else                         //add newNode at the end
    {
            rear->link = newNode;
            rear = rear->link;
    }
}//end addQueue

template<class Type>
void linkedQueueType<Type>::deQueue(Type& deqElement)
{
      nodeType<Type> *temp;

      deqElement = front->info;  //copy the info of the first element
      temp = front;              //make temp point to the first node
      front = front->link;       //advance front to the next node
      delete temp;               //delete the first node

      if(front == NULL)          //if after deletion the queue is empty
            rear = NULL;           //set rear to NULL
}//end deQueue



template<class Type>
linkedQueueType<Type>::~linkedQueueType() //destructor
{
      nodeType<Type> *temp;

      while(front != NULL)        //while there are elements left in the queue
      {
         temp = front;          //set temp to point to the current node
         front = front ->link; //advance first to the next node
         delete temp;           //deallocate memory occupied by temp
      }

      rear = NULL;  // set rear to null
}

template<class Type>
const linkedQueueType<Type>& linkedQueueType<Type>::operator=
                                                    (const linkedQueueType<Type>&
otherQueue)
{
      //Write the definition of to overload the assignment operator
```

```
}

       //copy constructor
template<class Type>
linkedQueueType<Type>::linkedQueueType(const linkedQueueType<Type>& otherQueue)
{
    //Write the definition of the copy constructor
}//end copy constructor

#endif
//queue3.cpp
//Test Program linked queue

#include <iostream>
#include "queue3.h"

using namespace std;

int main()
{
       linkedQueueType<int> queue;
       int x, y;

       queue.initializeQueue();
       x = 4;
       y = 5;
       queue.addQueue(x);
       queue.addQueue(y);
       queue.deQueue(x);
       queue.addQueue(x + 5);
       queue.addQueue(16);
       queue.addQueue(x);
       queue.addQueue(y - 3);

       cout<<"Queue Elements: ";

       while(!queue.isEmptyQueue())
       {
              queue.deQueue(y);
              cout<<" "<<y;
       }

       cout<<endl;

       return 0;
}
```

output

Queue Elements: 5 9 16 4 2

//Deque1.cpp

```cpp
// deque::front
#include <iostream>
#include <deque>

int main ()
{
  std::deque<int> mydeque;

  mydeque.push_front(77);
  mydeque.push_back(20);

  mydeque.front() -= mydeque.back();

  std::cout << "mydeque.front() is now " << mydeque.front() << '\n';
  std::cout << "mydeque.back() is now " << mydeque.back() << '\n';

  return 0;
}
```

Output

```
mydeque.front() is now 57
mydeque.back() is now 20
```

// 5.21

```cpp
typedef string Elem;                                  // deque element type
  class LinkedDeque {                                 // deque as doubly linked list
  public:
    LinkedDeque();                            // constructor
    int size() const;                         // number of items in the deque
    bool empty() const;                               // is the deque empty?
    const Elem& front() const throw(DequeEmpty); // the first element
    const Elem& back() const throw(DequeEmpty);   // the last element
    void insertFront(const Elem& e);                  // insert new first element
    void insertBack(const Elem& e);                   // insert new last element
    void removeFront() throw(DequeEmpty);     // remove first element
    void removeBack() throw(DequeEmpty);      // remove last element
  private:                                    // member data
    DLinkedList D;                            // linked list of elements
    int n;                                    // number of elements
  };
```

// 5.22

```cpp
                                              // insert new first element
```

```
void LinkedDeque::insertFront(const Elem& e) {
  D.addFront(e);
  n++;
}
                                              // insert new last element
void LinkedDeque::insertBack(const Elem& e) {
  D.addBack(e);
  n++;
}
                                              // remove first element
void LinkedDeque::removeFront() throw(DequeEmpty) {
  if (empty())
    throw DequeEmpty("removeFront of empty deque");
  D.removeFront();
  n--;
}
                                              // remove last element
void LinkedDeque::removeBack() throw(DequeEmpty)  {
  if (empty())
    throw DequeEmpty("removeBack of empty deque");
  D.removeBack();
  n--;
}

//3.23
class DLinkedList {                                   // doubly linked list
public:
  DLinkedList();                                      // constructor
  ~DLinkedList();                                     // destructor
  bool empty() const;                                 // is list empty?
  const Elem& front() const;                          // get front element
  const Elem& back() const;                           // get back element
  void addFront(const Elem& e);             // add to front of list
  void addBack(const Elem& e);              // add to back of list
  void removeFront();                                 // remove from front
  void removeBack();                                  // remove from back
private:                                              // local type definitions
  DNode* header;                                      // list sentinels
```

```
  DNode* trailer;
 protected:                                    // local utilities
  void add(DNode* v, const Elem& e);           // insert new node before v
  void remove(DNode* v);                       // remove node v
 };
```

//3.24

```
DLinkedList::DLinkedList() {                   // constructor
    header = new DNode;                              // create sentinels
    trailer = new DNode;
    header->next = trailer;                    // have them point to each
other
    trailer->prev = header;
  }
  DLinkedList::~DLinkedList() {                      // destructor
    while (!empty()) removeFront();            // remove all but sentinels
    delete header;                             // remove the sentinels
    delete trailer;
  }
```

//3.25

```
bool DLinkedList::empty() const                // is list empty?
    { return (header->next == trailer); }

  const Elem& DLinkedList::front() const       // get front element
    { return header->next->elem; }

  const Elem& DLinkedList::back() const              // get back element
    { return trailer->prev->elem; }
```

//3.26

```
                                                     // insert new node
      before v
        void DLinkedList::add(DNode* v, const Elem& e) {
          DNode* u = new DNode;  u->elem = e;        // create a new node
      for e
          u->next = v;                         // link u in between v
          u->prev = v->prev;                         // ...and v->prev
          v->prev->next = v->prev = u;
        }

        void DLinkedList::addFront(const Elem& e)    // add to front of list
          { add(header->next, e); }

        void DLinkedList::addBack(const Elem& e)     // add to back of list
          { add(trailer, e); }
```

//3.27

```
  void DLinkedList::remove(DNode* v) {         // remove node v
    DNode* u = v->prev;                              // predecessor
    DNode* w = v->next;                              // successor
```

```
    u->next = w;                              // unlink v from list
    w->prev = u;
    delete v;
  }

  void DLinkedList::removeFront()             // remove from font
    { remove(header->next); }

  void DLinkedList::removeBack()              // remove from back
    { remove(trailer->prev); }
```

//5.23

```
typedef string Elem;                          // element type
  class DequeStack {                          // stack as a deque
  public:
    DequeStack();                             // constructor
    int size() const;                         // number of elements
    bool empty() const;                       // is the stack empty?
    const Elem& top() const throw(StackEmpty); // the top element
    void push(const Elem& e);                 // push element onto stack
    void pop() throw(StackEmpty);             // pop the stack
  private:
    LinkedDeque D;                            // deque of elements
  };
```

//5.24

```
DequeStack::DequeStack()                      // constructor
    : D() { }
                                              // number of elements
  int DequeStack::size() const
    { return D.size(); }
                                              // is the stack empty?
  bool DequeStack::empty() const
    { return D.empty(); }
                                              // the top element
  const Elem& DequeStack::top() const throw(StackEmpty) {
    if (empty())
      throw StackEmpty("top of empty stack");
    return D.front();
```

```
}
                                                    // push element onto stack
void DequeStack::push(const Elem& e)
  { D.insertFront(e); }
                                                    // pop the stack
void DequeStack::pop() throw(StackEmpty)
{
  if (empty())
    throw StackEmpty("pop of empty stack");
  D.removeFront();
}
```