Homework: Linear Data Structures – Stacks and Queues

This document defines the **homework assignments** for the ["Data Structures" course @ Software University](). Please submit a single **zip** / **rar** / **7z** archive holding the solutions (source code) of all below described problems.

Problem 1. Reverse Numbers with a Stack

Write a program that reads **N integers** from the console and **reverses them using a stack**. Use the **Stack<int>** class from .NET Framework. Just put the input numbers in the stack and pop them. Examples:

Input	Output
1 2 3 4 5	5 4 3 2 1
1	1
(empty)	(empty)
1 -2	-2 1

Problem 2. Calculate Sequence with a Queue

We are given the following sequence of numbers:

- $S_1 = N$
- $S_2 = S_1 + 1$
- $S_3 = 2*S_1 + 1$
- $S_4 = S_1 + 2$
- $S_5 = S_2 + 1$
- $S_6 = 2*S_2 + 1$
- $S_7 = S_2 + 2$
- …

Using the **Queue<T>** class, write a program to print its first 50 members for given N. Examples:

Input	Output
2	2, 3, 5, 4, 4, 7, 5, 6, 11, 7, 5, 9, 6, …
-1	-1, 0, -1, 1, 1, 1, 2, …
1000	1000, 1001, 2001, 1002, 1002, 2003, 1003, …

Problem 3. Implement an Array-Based Stack

Implement the "**stack**" data structure **Stack<T>** that holds its elements in an array:

```
public class ArrayStack<T>
{
    private T[] elements;
    public int Count { get; private set; }
    private const int InitialCapacity = 16;

    public ArrayStack(int capacity = InitialCapacity) { … }
    public void Push(T element) { … }
    public T Pop() { … }
```

```
    public T[] ToArray() { … }
    private void Grow() { … }
}
```

Follow the concepts from the **CircularQueue<T>** class from the exercises in class. The stack is simpler than the circular queue, so you will need to follow the same logic, but more simplified. Some hints:

- The stack **capacity** is **this.elements.Length**
- Keep the stack **size** (number of elements) in **this.Count**
- **Push(element)** just saves the **element** in **elements[this.Count]** and increases **this.Count**
- **Push(element)** should invoke **Grow()** in case of **this.Count == this.elements.Length**
- **Pop()** decreases **this.Count** and returns **this.elements[this.Count]**
- **Grow()** allocates a new array **newElements** of size **2 * this.elements.Length** and copies the first **this.Count** elements from **this.elements** to **newElements**. Finally, assign **this.elements = newElements**
- **ToArray()** just creates and returns a [sub-array](#) of **this.elements[0…this.Count-1]**

Problem 4. Array-Based Stack: Unit Tests

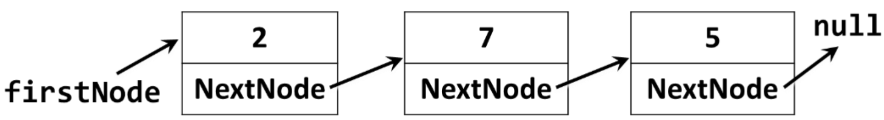
Write **unit tests** to ensure your array-based stack implementation works correctly. Test the following scenarios:

- **Push / pop element**: create a stack of numbers; assert Count == 0; push element; assert Count == 1; pop element; assert the element is the same like the pushed element; assert Count == 0.
- **Push / pop 1000 elements**: create a stack of strings; assert Count == 0; repeat 1000 times: { push element; assert the Count is correct; }; repeat 1000 times: { pop an element; assert the element is correct; assert the Count is correct }. Pushing 1000 elements will indirectly test the auto-grow functionality several times.
- **Pop from empty stack**: create a stack; pop an element; expect an exception;
- **Push / pop with initial capacity 1**: create a stack of numbers with initial capacity of 1; assert Count == 0; push element; assert Count == 1; push another element; assert Count == 2; pop element; assert the element is correct; assert Count == 1; pop element; assert the element is correct; assert Count == 0.
- **ToArray()**: create a stack of numbers; push a few numbers, e.g. { 3, 5, -2, 7 }; convert the stack to array; assert the results holds the pushed numbers in reversed order, e.g. { 7, -2, 5, 3 }.
- **Empty stack ToArray()**: create a stack of dates; convert the stack to array; expect empty array.

Use as reference the unit tests for the circular queue from the exercises.

Problem 5. Linked Stack

Implement a stack by a "**linked list**" as underlying data structure:



Use the following code as start:

```
public class LinkedStack<T>
{
    private Node<T> firstNode;
    public int Count { get; private set; }
    public void Push(T element) { … }
```

```
    public T Pop() { … }
    public T[] ToArray() { … }

    private class Node<T>
    {
        private T value;
        public Node<T> NextNode { set; set; }
        public Node(T value, Node<T> nextNode = null) { … }
    }
}
```

The **`Push(element)`** operation should create a new **`Node<T>`** and put it as **`firstNode`**, followed by the old value of the **`firstNode`**, e.g. **`this.firstNode = new Node<T>(element, this.firstNode)`**.

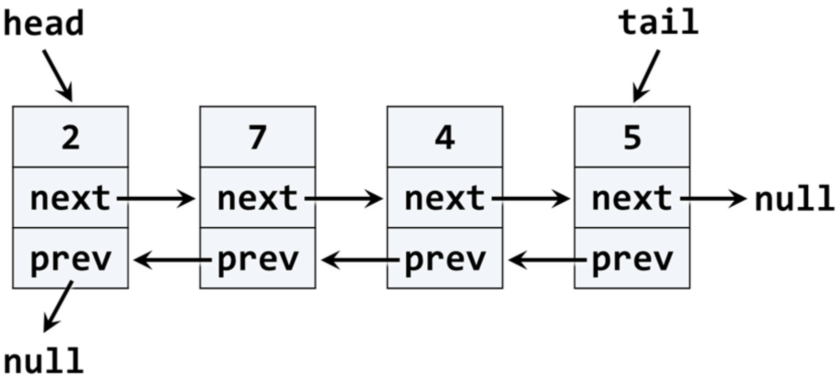
The **`Pop()`** operation should return the **`firstNode`** and replace it with **`firstNode.NextNode`**.

Problem 6. Linked Stack: Unit Tests

Write **unit tests** to ensure your linked stack implementation works correctly. Adjust the array-based stack unit tests.

Problem 7. Linked Queue

Implement a queue by a "**doubly-linked list**" as underlying data structure:



Use the following code as start:

```
public class LinkedQueue<T>
{
    public int Count { get; private set; }
    public void Enqueue(T element) { … }
    public T Dequeue() { … }
    public T[] ToArray() { … }

    private class QueueNode<T>
    {
        public T Value { get; private set; }
        public QueueNode<T> NextNode { get; set; }
        public QueueNode<T> PrevNode { get; set; }
    }
}
```

You may modify and adjust the code from the **`DoublyLinkedList<T>`** class from few lessons ago.

Problem 8. Linked Queue: Unit Tests

Write **unit tests** to ensure your linked queue is implemented correctly. Adjust the unit tests from the linked stack.

Problem 9. * Sequence N → M

We are given numbers **n** and **m**, and the following operations:

a) n → n + 1
b) n → n + 2
c) n → n * 2

Write a program that **finds the shortest sequence of operations** from the list above that **starts from n and finishes in m**. If several shortest sequences exist, find one of them. Examples:

Input	Output
`3 10`	`3 -> 5 -> 10`
`5 -5`	`(no solution)`
`10 30`	`10 -> 12 -> 14 -> 28 -> 30`

Hint: use a **queue** and the following algorithm:

1. create a queue of numbers
2. queue ← n
3. while (queue not empty)
    1. queue → e
    2. if (e < m)
        i. queue ← e + 1
        ii. queue ← e + 2
        iii. queue ← e * 2
    3. if (e == m) Print-Solution; exit

The above algorithm either will find a solution, or will find that it does not exist. It cannot print the numbers comprising the sequence n → m.

To print the sequence of steps to reach **m**, starting from **n**, you will need to keep the previous item as well. Instead using a queue of numbers, use a queue of items. Each item will keep a number and a pointer to the previous item. The algorithms changes like this:

Algorithm Find-Sequence (n, m):

1. create a queue of items { value, previous item }
2. queue ← { n, **null** }
3. while (queue not empty)
    1. queue → item
    2. if (item.value < m)
        i. queue ← { item.value + 1, item }
        ii. queue ← { item.value + 2, item }
        iii. queue ← { item.value * 2, item }
    3. if (item.value == m) Print-Solution; exit

Algorithm Print-Solution (item):

1. while (item not null)
    1. print item.value
    2. item = item.previous