Chap 3. Stacks and Queues (1)

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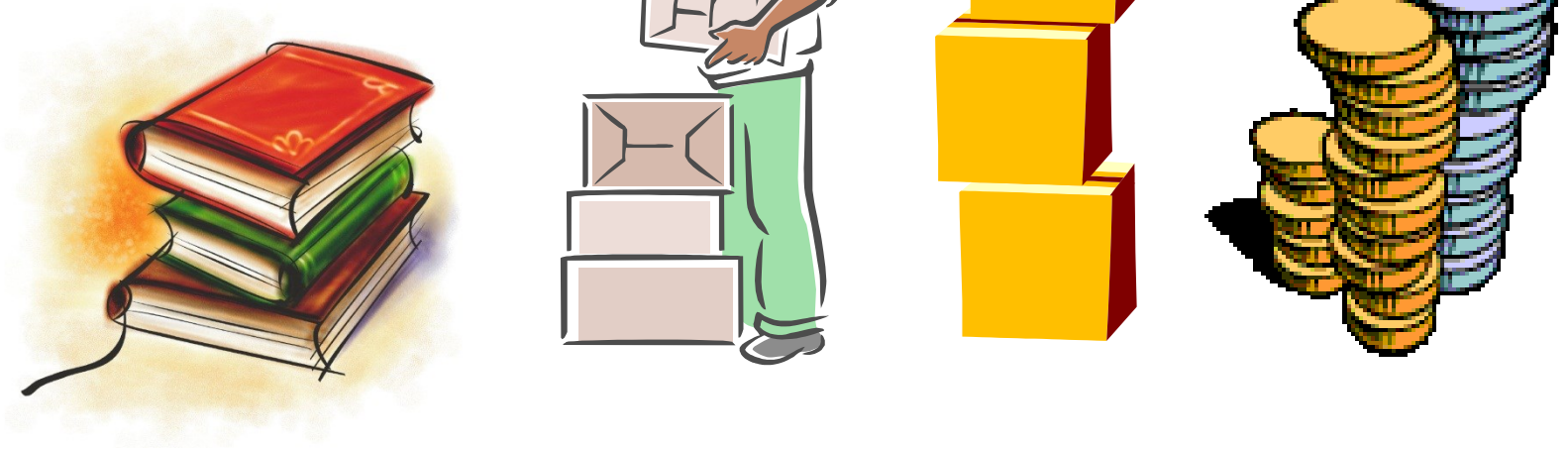
Contents

3.1 Stacks



3.1 Stacks

- *Linear list*.
- One end is called *top*.
- The other end is called *bottom*.
- Additions to and removals from the *top* end only.

- A stack is a LIFO list.
  - *Last-In-First-Out*

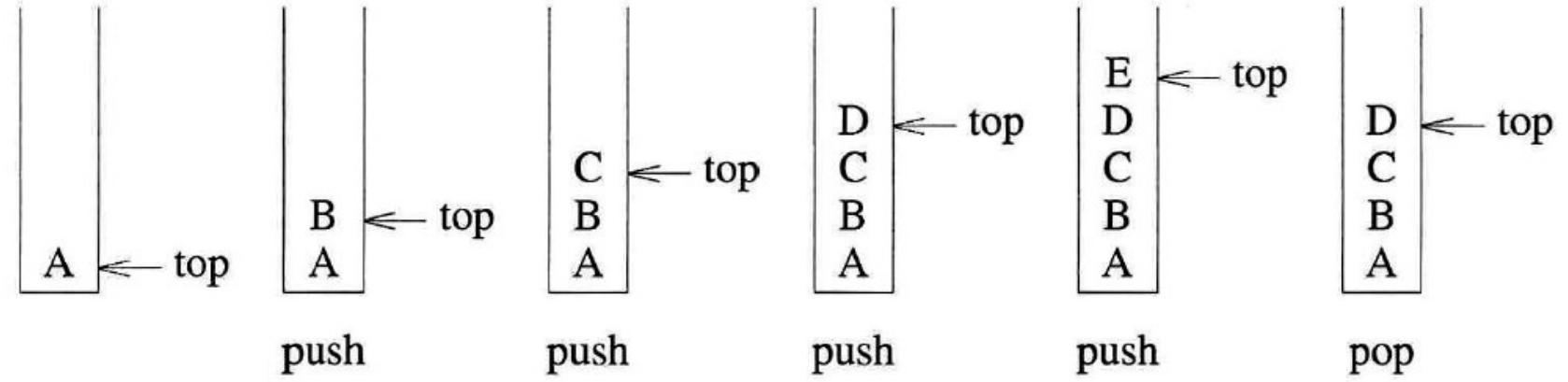


Figure 3.1: Inserting and deleting elements in a stack

ADT *Stack* is

objects: a finite ordered list with zero or more elements.

functions:

for all *stack* ∈ *Stack*, *item* ∈ *element*, *maxStackSize* ∈ positive integer

Stack CreateS(*maxStackSize*) ::=
create an empty stack whose maximum size is *maxStackSize*

Boolean IsFull(*stack*, *maxStackSize*) ::=
if (number of elements in *stack* == *maxStackSize*)
return *TRUE*
else return *FALSE*

Stack Push(*stack*, *item*) ::=
if (IsFull(*stack*)) *stackFull*
else insert *item* into top of *stack* and **return**

Boolean IsEmpty(*stack*) ::=
if (*stack* == CreateS(*maxStackSize*))
return *TRUE*
else return *FALSE*

Element Pop(*stack*) ::=
if (IsEmpty(*stack*)) **return**
else remove and return the element at the top of the stack.

ADT 3.1: Abstract data type *Stack*

- Creation of Stack in C
  - Use a *1D array* to represent a stack.
  - Stack elements are stored in *stack[0] through stack[top]*.

Stack CreateS(*maxStackSize*) ::=

```
#define MAX_STACK_SIZE 100 /* maximum stack size */
typedef struct {
        int key;
        /* other fields */
        } element;
element stack[MAX_STACK_SIZE];
int top = -1;
```

Boolean IsEmpty(Stack) ::=

Boolean IsFull(Stack) ::=

- Implementation of Stack Operations

```
void push(element item)
{/* add an item to the global stack */
   if (top >= MAX_STACK_SIZE-1)
      stackFull();
   stack[      ] = item;
}
```

Program 3.1

```
element pop()
{/* delete and return the top element from the stack */
   if (top == -1)
      return stackEmpty(); /* returns an error key */
   return stack[      ];
}
```

Program 3.2

```
void stackFull()
{
   fprintf(stderr, "Stack is full, cannot add element");
   exit(EXIT_FAILURE);
}
```

Program 3.3

3.2 Stacks Using Dynamic Arrays

Stack CreateS() ::=
```
typedef struct {
        int key;
        /* other fields */
        } element;
element *stack;
MALLOC(stack, sizeof(*stack));
int capacity = 1;
int top = -1;
```

※ **capacity** : maximum number of stack elements that may be stored in the array

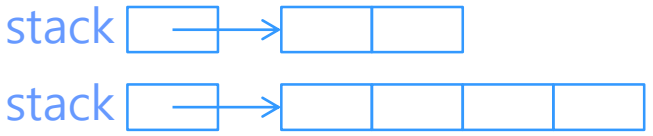
Boolean IsEmpty(Stack) ::=

Boolean IsFull(Stack) ::=

- *pop* : unchanged from Program 3.2
- *push, stackFull* : changed from Program 3.1&3.3
- ***Array Doubling***
  - When stack is full, double the capacity using REALLOC.

```
void stackFull()
{
   REALLOC(oldStack, stack, 2*capacity*sizeof(int));
   capacity *= 2;
}
```

Program 3.4: Stack full with array doubling

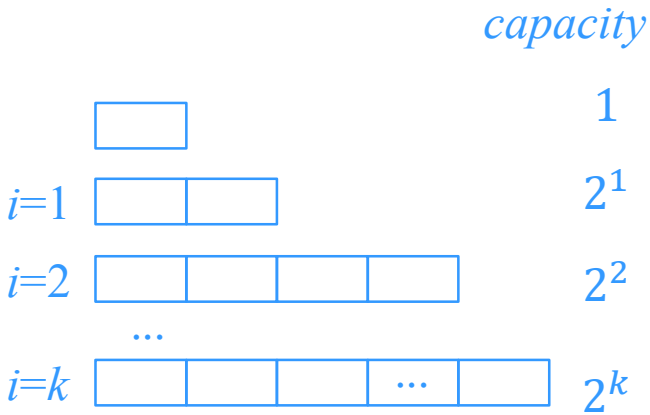


...

- Time complexity of array doubling
  - One array doubling
    - Memory allocation : O(1)
    - Copy of an array element : O(1)
    - Copy of all array elements : O(capacity)
  - All array doubling
    - *N 번의 push 가 있었고 현재 stack capacity 가 2^k 이라면 (k번 doubling)*

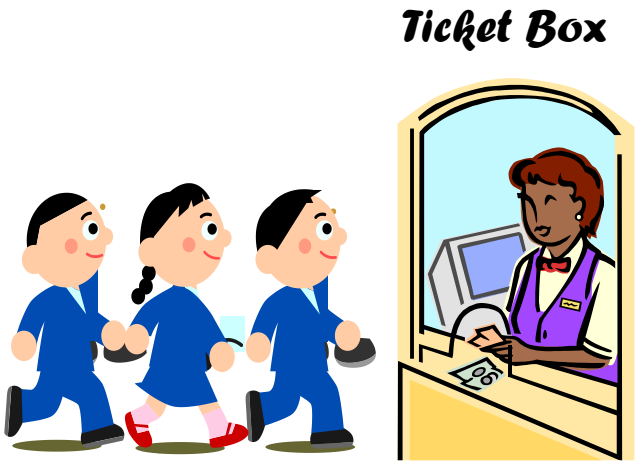
$$O\left(\sum_{i=1}^{k} 2^i\right) = O(2^{k+1}) = O(2^k)$$

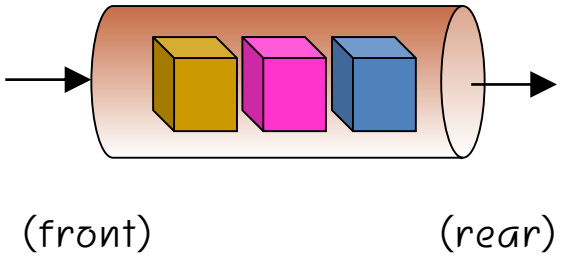
Doubling 시 copy수



What is difference between stack and Array?

3.3 Queues





3.3 Queues

- *Linear list*.
- One end is called *front*.
- The other end is called *rear*.
- *Additions* are done at the *rear* only.
- *Removals* are made from the *front* only.

- A queue is a FIFO list.
  - *First-In-First-Out*

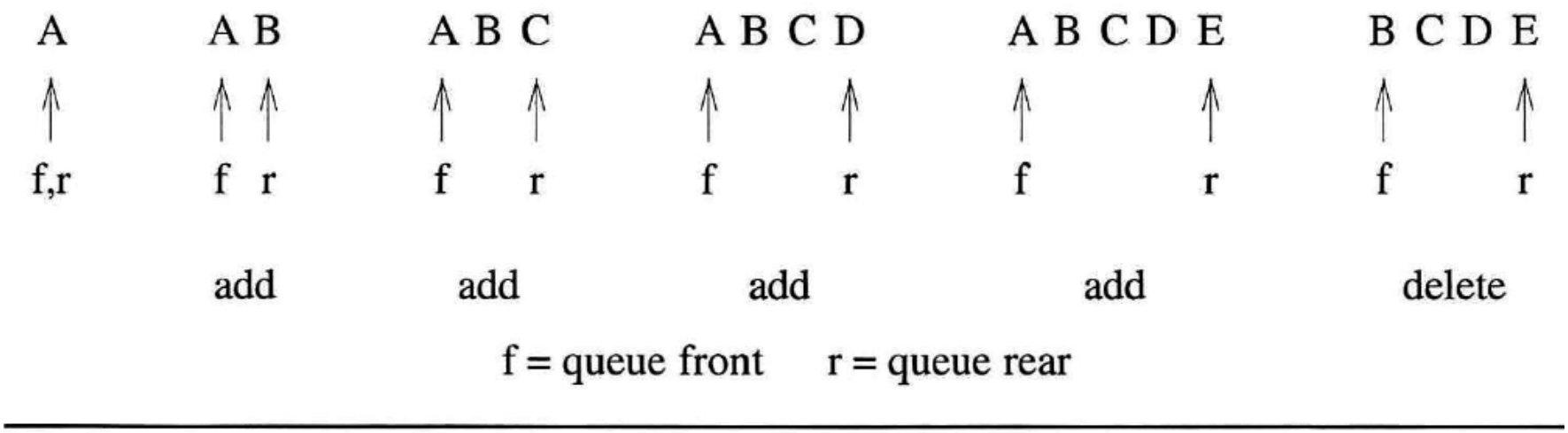


Figure 3.4: Inserting and deleting elements in a queue

ADT *Queue* is

objects: a finite ordered list with zero or more elements.

functions:

for all *queue* ∈ *Queue*, *item* ∈ *element*, *maxQueueSize* ∈ positive integer

Queue CreateQ(*maxQueueSize*) ::=
create an empty queue whose maximum size is *maxQueueSize*

Boolean IsFullQ(*queue*, *maxQueueSize*) ::=
if (number of elements in *queue* == *maxQueueSize*)
return *TRUE*
else return *FALSE*

Queue AddQ(*queue*, *item*) ::=
if (IsFullQ(*queue*)) *queueFull*
else insert *item* at rear of *queue* and return *queue*

Boolean IsEmptyQ(*queue*) ::=
if (*queue* == CreateQ(*maxQueueSize*))
return *TRUE*
else return *FALSE*

Element DeleteQ(*queue*) ::=
if (IsEmptyQ(*queue*)) **return**
else remove and return the *item* at front of queue.

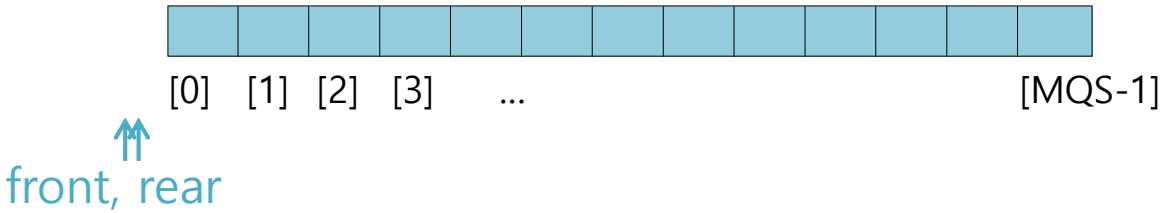
ADT 3.2: Abstract data type *Queue*

Representations of Queue

- Sequential representation
  - Uses an *1D array*
- Circular representation : *circular queue*
  - Uses an *1D array*
  - More efficient

Sequential Representation

- Creation of Queue in C
  - Uses an 1D array, *queue*



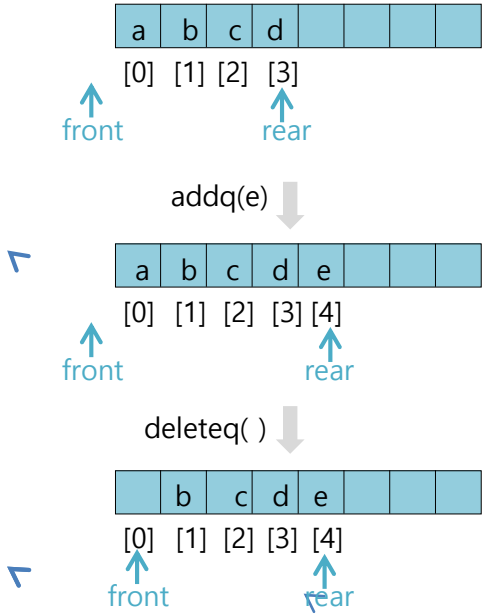

```
Queue CreateQ(maxQueueSize) ::=
        #define MAX_QUEUE_SIZE 100 /* maximum queue size */
        typedef struct {
                int key;
                /* other fields */
                } element;
        element queue[MAX_QUEUE_SIZE];
        int rear = -1;
        int front = -1;
Boolean IsEmptyQ(queue) ::=

Boolean IsFullQ(queue) ::=
```

- Implementation of Queue Operations

```
void addq(element item)
{/* add an item to the queue */
   if (rear == MAX_QUEUE_SIZE-1)
      queueFull();
   queue[++rear] = item;
}
```

Program 3.5: Add to a queue




```
element deleteq()
{/* remove element at the front of the queue */
   if (front == rear)
      return queueEmpty(); /* return an error key */
   return queue[          ];
}
```

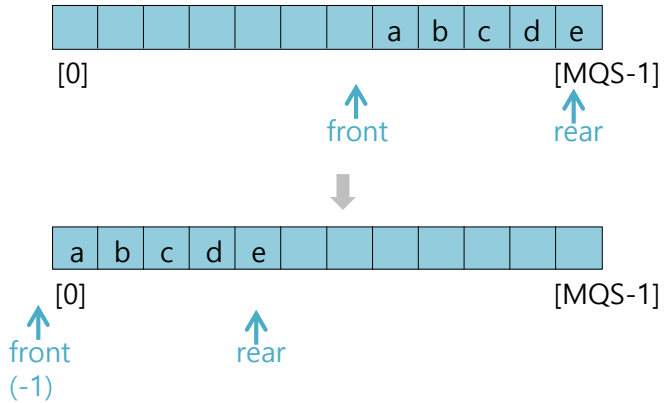
Program 3.6: Delete from a queue

- Example: Job Scheduling by an OS

front	*rear*	*Q*[0]	*Q*[1]	*Q*[2]	*Q*[3]	Comments
−1	−1					queue is empty
−1	0	J1				Job 1 is added
−1	1	J1	J2			Job 2 is added
−1	2	J1	J2	J3		Job 3 is added
0	2		J2	J3		Job 1 is deleted
1	2			J3		Job 2 is deleted

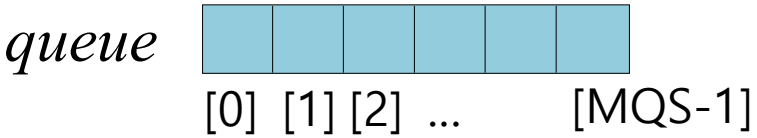
Figure 3.5: Insertion and deletion from a sequential queue

– queueFull
  - array shifting : time-consuming
  - Worst case time complexity, *O(MAX_QUEUE_SIZE)*

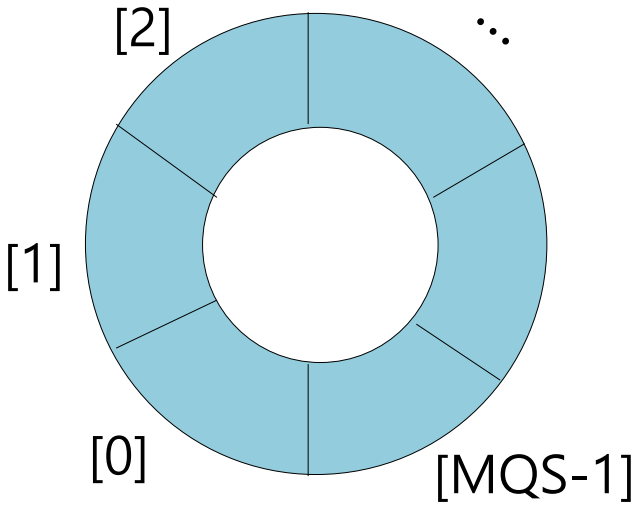


Circular Queue

- Uses an 1D array, *queue*



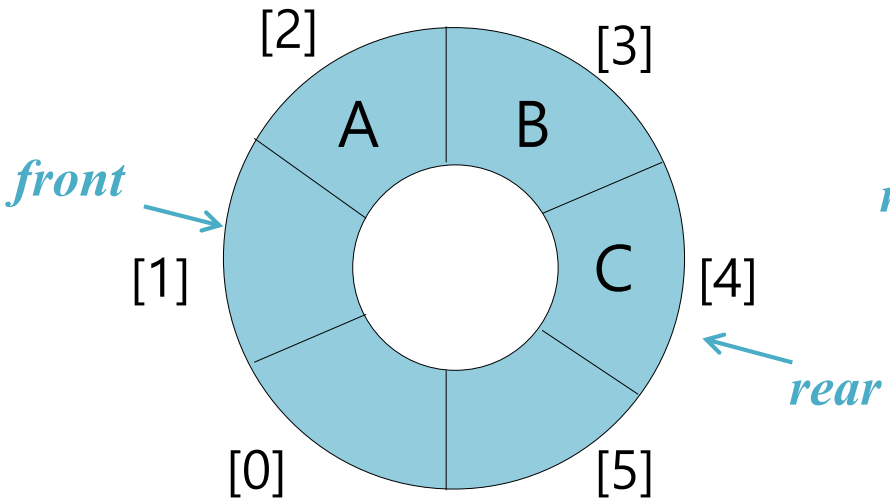
- Circular view of an 1D array

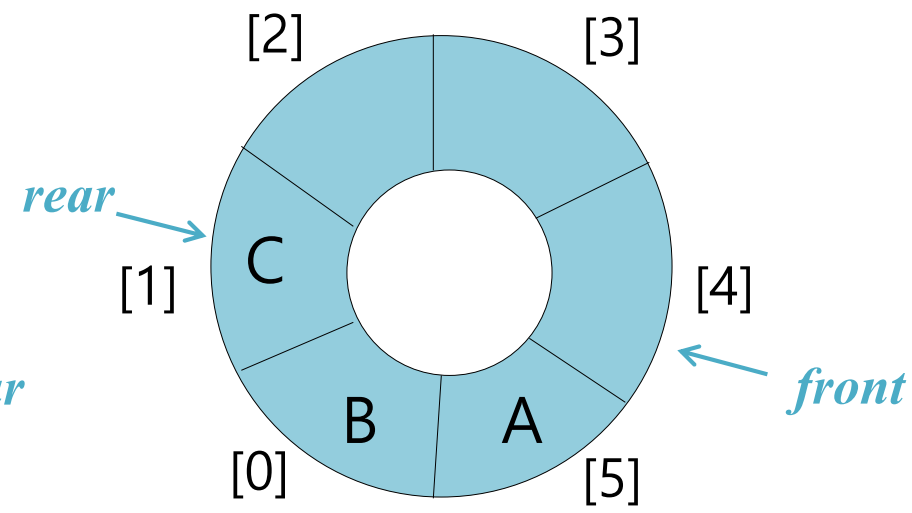


Initial values
front = *rear* = 0

Circular Queue

- integer variables *front* and *rear*.
  - *front* is *one position counterclockwise from first element*
  - *rear* gives position of last element





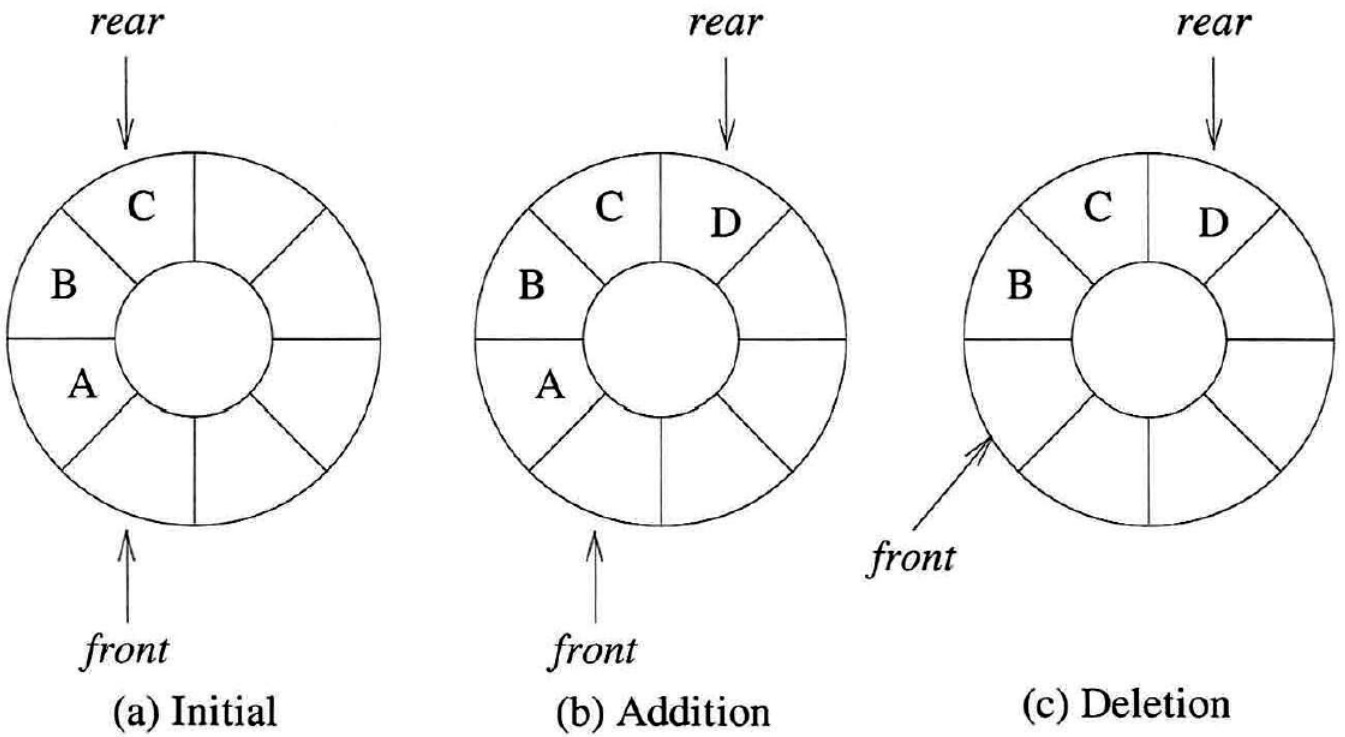
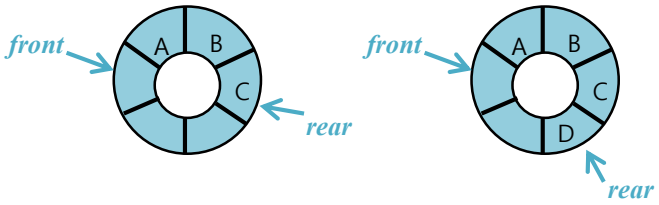


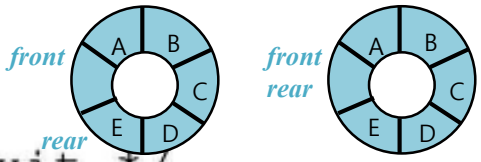
Figure 3.6: Circular queue

Circular Queue

- Add an element in the circular queue.
  - Move *rear* one clockwise.
  - Queue Full Check
  - Then put into *queue*[*rear*].




```
void addq(element item)
{/* add an item to the queue */
   [redacted]
   if ([redacted])
      queueFull(); /* print error and exit */
   queue[rear] = item;
}
```

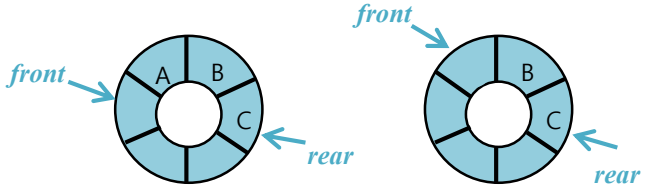


Program 3.7: Add to a circular queue

a maximum of MAX_QUEUE_SIZE-1 elements in the queue at any time!

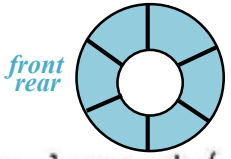
Circular Queue

- Delete an element from the circular queue.
  - Queue Empty check
  - Move *front* one clockwise.
  - Then extract from *queue*[*front*].




```
element deleteq()
{/* remove front element from the queue */

     if (front == rear)
        return queueEmpty(); /* return an error key */
     front = (front+1) % MAX_QUEUE_SIZE;
     return queue[front];
}
```



Program 3.8: Delete from a circular queue