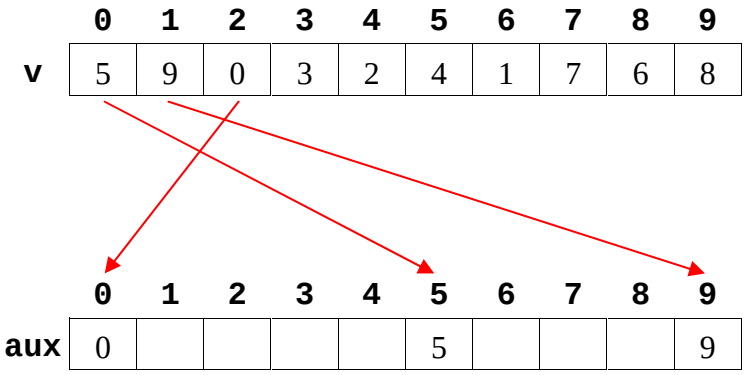
THE COUNTING SORT

The ***counting sort*** is an efficient algorithm for sorting values that have a limited range. It was invented by Harold H. Seward in the mid 1950s.

Suppose you have an array *v* containing *m* integers, each within the range 0 to *m*−1, shuffled into random order. You can sort these integers simply by moving each integer into its correct position within an auxiliary array.

Example

The picture below shows how the first three items in array **v** are moved into their correct positions within the auxiliary array.



Here's the counting sort algorithm:

Counting Sort Algorithm

```
int [] aux = new int[m];
for ( int k=0; k < m; k++ )
   aux[v[k]] = v[k];
```

A more realistic situation assumes that array *v* contains *n* integers in the range 0 to *m*−1, where *m* is within some constant factor of *n* (i.e. $m < cn$ for some constant $c > 0$). Also, duplicate values are allowed. Under these conditions, the counting sort works in three passes. The first pass counts each integer in *v*:

Revised Counting Sort Algorithm
Pass 1

```
int [] count = new int[m];
for ( int k=0; k < n; k++ )
   count[v[k]]++;
```

Example

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
v	0	3	3	0	1	1	0	3	0	2	0	1	1	2	0

	0	1	2	3
count	6	4	2	3

Each integer *k* occupies **`count[`***k***`]`** positions in the final sorted array. If integer *k* starts at position *p* then, for it to occupy **`count[`***k***`]`**, integer *k*+1 must start at position *p*+**`count[`***k***`]`**.

Example, continued

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
v	0	3	3	0	1	1	0	3	0	2	0	1	1	2	0

	0	1	2	3
count	6	4	2	3

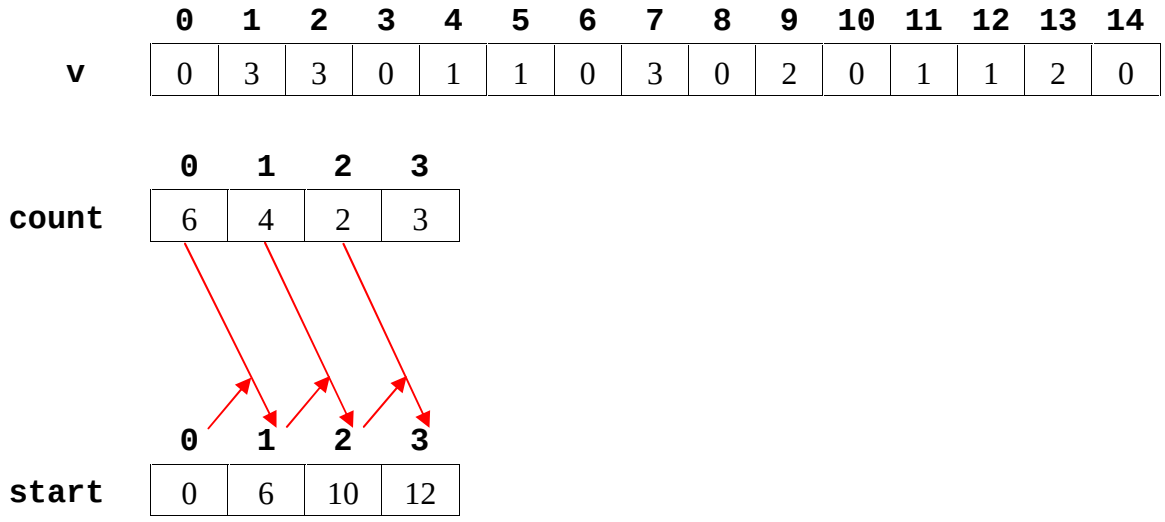
In the sorted array, integer 0 starts at position 0 and occupies **`count[0]`** = 6 positions. Thus, integer 1 starts at position 0+6 = 6. Likewise, integer 2 starts at position 6 + **`count[1]`** = 6 + 4 = 10.

The second pass of the algorithm calculates all of these starting positions and places them into a third array.

Revised Counting Sort Algorithm
Pass 2

```
int [] start = new int[m];
start[0] = 0;
for ( int k=1; k < m; k++ )
   start[k] = start[k-1] + count[k-1];
```

Example, continued



The third and final pass distributes each integer in the original array *v* to its final position in the sorted array:

Revised Counting Sort Algorithm
Pass 3

```
int [] fin = new int[n];
for ( int k=0; k < n; k++ )
   fin[ start[ v[k] ]++ ] = v[k];
```

Example, concluded

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
v	0	3	3	0	1	1	0	3	0	2	0	1	1	2	0

	0	1	2	3
count	6	4	2	3

	0	1	2	3
start	0	6	10	12

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
fin	0	0	0	0	0	0	1	1	1	1	2	2	3	3	3

Programming Exercises

1.	Implement the revised counting sort algorithm as the following Java method:
	
	`int [] countingSort( int [] v, int m )`
	`// Use Seward's counting sort algorithm that`
	`// returns an array containing the items in 'v'`
	`// in ascending order.`
	`// Each v[k] is in the range 0 to m.`
	
	Write an application to test your method. The application must create an unsorted array, call your method to sort it and print the results.