10.2 Arrays

Name: _____ Class: _____ Date: _____ **Total: 35 marks**

KEY WORDS bounds • linear search • index • element • arrays

Objective

An **array** lets a weather station store, search and process many readings using loops.

Learn: declarations, bounds, tracing, totals, counts, searching and array processing. Continue with **10.2.1** for bubble sort and insertion/deletion, then **10.2.2** for combined exam practice.

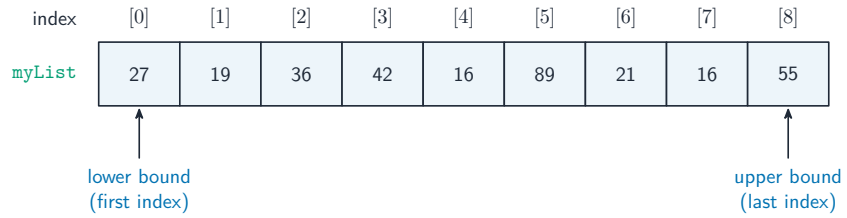
1 Key knowledge and worked examples

■ Elements, indices and bounds

An array holds a fixed number of same-type **elements**, each reached by an integer **index**. **Lower bound** and **upper bound** are the first and last valid indices, both included. A **dimension** is one indexing direction.

```
DECLARE Scores : ARRAY[0:4] OF INTEGER
Scores[3] ← 75
```

`Scores[3]` is the fourth element; `Scores[5]` is invalid. Number of elements = upper bound − lower bound + 1, so this array holds $4 - 0 + 1 = 5$ elements. Indices need not start at 1.



Use **1-D** for a sequence; **2-D** for two directions, such as month and shop. Declare all bounds and the type. Declaration does not initialise values.

■ Initialise, input, total and count

Worked example: enter five marks, output the mean and count marks at least 50. Replace `INPUT Mark[Index]` with `Mark[Index] ← 0` to initialise elements.

```
DECLARE Mark : ARRAY[1:5] OF INTEGER
DECLARE Index, Total, PassCount : INTEGER
Total ← 0
PassCount ← 0
FOR Index ← 1 TO 5
    INPUT Mark[Index]
    Total ← Total + Mark[Index]
    IF Mark[Index] >= 50 THEN
        PassCount ← PassCount + 1
    ENDIF
NEXT Index
OUTPUT "Mean: ", Total / 5, ", passes: ", PassCount
```

For `40, 50, 70, 20, 80`: total `260`, mean `52`, count `3`. A total adds **values**; a count adds **one**. Initialise before the loop; output afterwards. Trace updates in statement order.

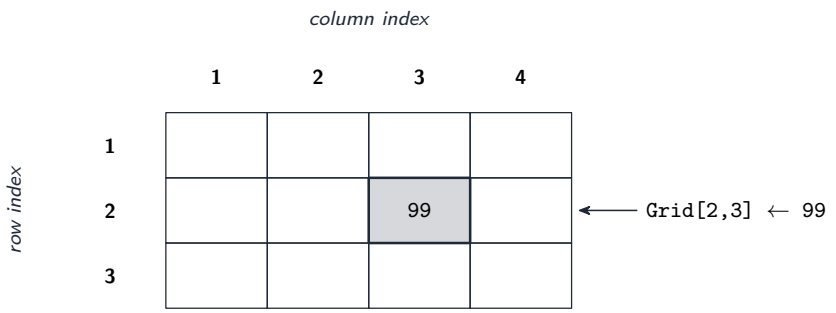
■ Largest value and its position

For non-empty integer array `A[1:n]`, start with its first value. Starting at zero fails for all-negative data.

```
DECLARE Index, Largest, Position : INTEGER
Largest ← A[1]
Position ← 1
FOR Index ← 2 TO n
    IF A[Index] > Largest THEN
        Largest ← A[Index]
        Position ← Index
    ENDIF
NEXT Index
OUTPUT "Largest: ", Largest, ", index: ", Position
```

For `-8, -2, -2, -5`, the maximum is `-2` at index `2`. `>` keeps the first tie; `>=` keeps the last. Reverse the comparison for a minimum.

Two dimensions: rows, columns and totals




```
DECLARE Grid : ARRAY[1:3, 1:4] OF INTEGER
Grid[2, 3] ← 99
```

There are $3 \times 4 = 12$ elements. Here the first index is row, the second column; follow the question's convention.

Worked example: `Grid` is filled. Output each row total and the whole-grid total.

```
DECLARE Row, Col, RowTotal, GrandTotal : INTEGER
GrandTotal ← 0
FOR Row ← 1 TO 3
    RowTotal ← 0
    FOR Col ← 1 TO 4
        RowTotal ← RowTotal + Grid[Row, Col]
    NEXT Col
    OUTPUT "Row ", Row, ": ", RowTotal
    GrandTotal ← GrandTotal + RowTotal
NEXT Row
OUTPUT GrandTotal
```

Reset `RowTotal` per row. For column totals, put columns in the outer loop. For one row, fix the row index and loop over columns.

Linear search: return the first match

A **linear search** checks in order. This function uses global integer array `A[1:n]`, with `n >= 1`. A function returns a value; a procedure has no return value.

```
FUNCTION FindFirst(Target : INTEGER) RETURNS INTEGER
    DECLARE Index, FoundAt : INTEGER
    Index ← 1
    FoundAt ← -1
    WHILE Index <= n AND FoundAt = -1
        IF A[Index] = Target THEN
            FoundAt ← Index
        ENDIF
        Index ← Index + 1
    ENDWHILE
    RETURN FoundAt
ENDFUNCTION
```

For `4, 7, 7, 2`, searching for `7` returns `2`; `9` returns `-1`. Stop at the first match. Both `0` and `-1` could mean failure here: choose a value outside the **declared** bounds.

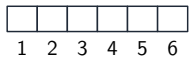
Capacity and used elements

Capacity is the number allocated; `Count` is the number used. In `Data[1:20]` with `Count = 3`, process only `1:3`. Before adding, check `Count < 20`, increment it, then assign `Data[Count]`.

2 Practice

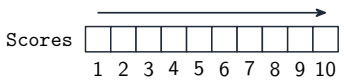
Now apply the methods above.

2.1 Explain the array terms **element** and **bounds**. [2]

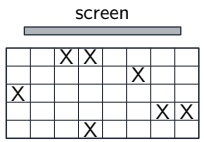


2.2 Declare a 1-D array `Scores` of **10** integers, then set the **4th** element to `75`. [2]

2.3 Write a `FOR` loop to output **all 10** elements of `Scores`. [2]

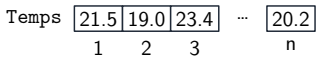


2.4 A cinema has **5** rows and **8** seats per row, each marked `'F'` (free) or `'X'` (taken). Declare a suitable **2-D** array `Seats`. [2]

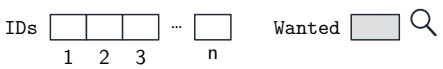


3 Exam-style questions

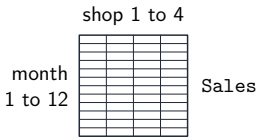
3.1 Array `Temps[1:n]` holds `n` real temperatures, where `n >= 1`. Write pseudocode to find and output the **largest** value. [4]



3.2 Write pseudocode for a **linear search** of `IDs[1:n]` for a value `Wanted`. Output the position of the **first** match, or `"Not found"` if it is absent. Assume `n >= 1`; stop searching once a match is found. [4]



3.3 Global array `Sales[1:12, 1:4]` contains real monthly sales. Row = month; column = shop. Write pseudocode to output the annual total for **each** shop and the number of months in which that shop's sales were above `10000`. Declare local variables. [6]

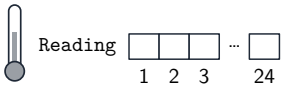


3.4 A weather station stores the last 24 hourly temperature readings in a 1D array `Reading` of type `REAL`, indexed from 1 to 24.

(a) **Complete** procedure `Store()`, which inputs 24 real readings and stores them in consecutive array elements. [5]

```
PROCEDURE Store()
    DECLARE Index : ....................
    FOR Index ← 1 TO ....................
        .................... Reading[....................]
    .................... Index
ENDPROCEDURE
```

(b) Explain why a running maximum should start at `Reading[1]` rather than `0`. [1]



(c) A function `FindFirstAbove(Limit)` returns the **index** of the first reading above `Limit`, or -1 if there is none. Explain why -1 is suitable for "not found", and whether 0 would also be suitable for this declaration. [2]

(d) **Write** pseudocode for the function `FindFirstAbove()`, which takes the real parameter `Limit`. Stop searching as soon as a reading above `Limit` is found. [5]

Solutions

Each answer shows the steps, then the **result**.

2.1

- **element** – one item stored in the array
- **bounds** – the lowest and highest valid index values

2.2

- declare the array, then assign one element

```
DECLARE Scores : ARRAY[1:10] OF INTEGER
Scores[4] ← 75
```

- also accept `ARRAY[0:9]` with `Scores[3] ← 75`: the 4th element follows from the lower bound

2.3

- loop from 1 to 10 and output each element

```
FOR i ← 1 TO 10
    OUTPUT Scores[i]
NEXT i
```

- for `ARRAY[0:9]`, loop `FOR i ← 0 TO 9`; the loop bounds must match the declared bounds

2.4

- 2-D `ARRAY[…, …]` of `CHAR`
- `DECLARE Seats : ARRAY[1:5, 1:8] OF CHAR`

3.1

- initialise `Max` to the first element, then scan the rest

```
DECLARE i : INTEGER
DECLARE Max : REAL
Max ← Temps[1]
FOR i ← 2 TO n
    IF Temps[i] > Max THEN
        Max ← Temps[i]
    ENDIF
NEXT i
OUTPUT Max
```

- compare + update; `OUTPUT` after the loop

3.2

- initialise index and failure value; bounded conditional loop; compare and keep first position; output found/not found after loop.

```
DECLARE Index, FoundAt : INTEGER
Index ← 1
FoundAt ← -1
WHILE Index <= n AND FoundAt = -1
    IF IDs[Index] = Wanted THEN
        FoundAt ← Index
    ENDIF
    Index ← Index + 1
ENDWHILE
IF FoundAt = -1 THEN
    OUTPUT "Not found"
ELSE
    OUTPUT FoundAt
ENDIF
```

3.3

- local declarations; outer loop for shops; reset totals/counts per shop; inner loop over months; total and conditional count; output each shop's results after its month loop.

```
DECLARE Shop, Month, Count : INTEGER
DECLARE Total : REAL
FOR Shop ← 1 TO 4
    Total ← 0
    Count ← 0
    FOR Month ← 1 TO 12
        Total ← Total + Sales[Month, Shop]
        IF Sales[Month, Shop] > 10000 THEN
            Count ← Count + 1
        ENDIF
    NEXT Month
    OUTPUT "Shop ", Shop, ": ", Total, ", months: ", Count
NEXT Shop
```

3.4

(a) `INTEGER`; `24`; `INPUT`; `Index`; `NEXT`.

(b) all readings could be negative, so starting at zero could output a value that is not in the array.

(c)

- valid indices are 1 to 24, so -1 cannot be confused with a matching index
- 0 would also work for this declaration, because it is outside these bounds; it would not work if 0 were a valid index

(d)

```
FUNCTION FindFirstAbove(Limit : REAL) RETURNS INTEGER
    DECLARE FoundAt, Index : INTEGER
    FoundAt ← -1
    Index ← 1
    WHILE Index <= 24 AND FoundAt = -1
        IF Reading[Index] > Limit THEN
            FoundAt ← Index
        ELSE
            Index ← Index + 1
        ENDIF
    ENDWHILE
    RETURN FoundAt
ENDFUNCTION
```

- header with parameter and return type; `FoundAt` initialised to -1; loop with both conditions; correct comparison; `RETURN`