

Exercise walk-through

11.3.3

Efficient pseudocode, structure charts and breaking a task into modules

A-Level Computer Science

You must be able to

- explain where in the construction of an algorithm it is appropriate to use a procedure, and where a function
- write efficient pseudocode: no work repeated that could be done once, and no test made that the answer is already known
- break a described task into modules, and give each one a header and an **interface**
- read a structure chart: what a box is, what a downward arrow is, and what the small side arrows carry
- explain why modules are tested on their own before being combined

1

The method

Method — What “efficient” means in this syllabus

Efficiency here is not about big-O. It is four concrete habits the mark scheme rewards:

- 1 Move unchanging work out of the loop.** `LENGTH(InString)` does not change while the loop runs, so compute it once into a local and use that.
- 2 Stop as soon as the answer is known.** Add the flag to the loop condition – `WHILE Index <= Num AND IsPal = TRUE` – or `RETURN` immediately.
- 3 Do not test what you already know.** After `IF Mark >= 70`, a later test only needs `Mark >= 60`, never `Mark < 70 AND Mark >= 60`.
- 4 Use arithmetic instead of a search.** A band of ten is `(Percent DIV 10) + 1`, not a loop or an eleven-branch `CASE`.

Method — What “efficient” means in this syllabus

Worked example. *Rewrite this so the same work is not repeated.*

```
FOR Index <- 1 TO LENGTH(InString)           // recomputed every
↪  pass
  IF MID(InString, Index, 1) <> " " THEN
    OutString <- OutString & MID(InString, Index, 1)
  ENDIF
NEXT Index
```

Method — What “efficient” means in this syllabus

```
DECLARE Len : INTEGER
Len <- LENGTH(InString)           // once
FOR Index <- 1 TO Len
  ThisChar <- MID(InString, Index, 1) // once per pass, not twice
  IF ThisChar <> " " THEN
    OutString <- OutString & ThisChar
  ENDIF
NEXT Index
```

Method — What “efficient” means in this syllabus

- Two changes, two marks: the length is found once, and each character is extracted once instead of twice.

Method — What “efficient” means in this syllabus

Efficiency here is not about big-O.

slower

```
FOR i = 1 TO n
  x = slow() // every
pass
  use(x, i)
NEXT i
```

faster

```
x = slow() // once
FOR i = 1 TO n
  use(x, i)
NEXT i
```

Move unchanging work out of the loop so it runs once

Method — Where the module boundaries go

Given a task in prose, the boundaries fall where the **jobs** fall. Ask of each job:

- Is it needed **in more than one place**, or does it simply have to be *done*? Make it a **procedure**.
- Does it produce **one value** the rest of the algorithm then uses? Make it a **function**.
- Does it change something the caller must see, but produce no single value? A procedure with a BYREF parameter.

Worked example. *A program reads a file of marks, validates each one, works out the average and prints a report. Three modules:*

Module	Kind	Header
read and validate one mark	function	FUNCTION GetMark() RETURNS INTEGER
work out the average of a total and a count	function	FUNCTION Average(Total : INTEGER, Count : INTEGER) RETURNS REAL
print the report	procedure	PROCEDURE PrintReport(Av : REAL, Count : INTEGER)

Method — Where the module boundaries go

- Name each module for the **one** job it does. A module you cannot name in a few words is doing two jobs.
- A procedure may have **none**, one or more parameters. PROCEDURE ShowMenu() needs none at all, because it works on nothing the caller supplies. Where there are parameters, decide for each one separately whether it is passed by value or by **reference**.

Method — Where the module boundaries go

Given a task in prose, the boundaries fall where the jobs fall.

```
FUNCTION CountAbove(BYVAL Limit : INTEGER) RETURNS INTEGER
  DECLARE Index, Count : INTEGER
  Count ← 0
  FOR Index ← 1 TO 50
    IF Score[Index] > Limit THEN
      Count ← Count + 1
    ENDIF
  NEXT Index
  RETURN Count
ENDFUNCTION
```

..... RETURNS INTEGER parameters, return type

..... local variables declared with a type

..... total initialised before the loop

..... loop over every element

..... the condition, with the right boundary

..... the update, inside the IF

..... every construct closed

..... the return value, after the loop

Method — Reading a structure chart

A structure chart shows the same decomposition as a picture:

- a **box** is a module,
- a **downward line** from one box to another means the upper module **calls** the lower one,
- the small arrows beside that line are the **parameters**: an arrow pointing **down** into the lower module is data passed in, and an arrow pointing **up** is data returned.

So a lower box with only a downward arrow is doing something with data it is given; one with an upward arrow is handing a value back, which usually means it is a function. Reading the chart tells you each module's **interface** without seeing any code, and the **terminology associated** with procedures and functions is what the question will use to ask about it: the **header** names the module and its **parameters**, the caller supplies the matching **arguments**, and an upward arrow is the **return value**.

Method — Testing the pieces, then the whole

- **Module (unit) testing** – each module is tested on its own, with values chosen to exercise it, before the program is assembled.
- **Integration testing** – modules that have already been tested individually are combined into a single sub-program, which is then tested as a whole.
- This is the payoff of writing self-contained modules with local variables and parameters: a module with no globals can be tested by itself, because everything it touches arrives through its interface.

2

Practice

Practice 2.1 ■ 3 marks

Rewrite this loop so that no work is repeated unnecessarily, and state the change you made.

```
FOR Index <- 1 TO LENGTH(Names)
  OUTPUT UCASE(MID(Names, Index, 1))
NEXT Index
```

Solution 2.1

Method: What “efficient” means in this syllabus — p.4

Worked steps

- `LENGTH(Names)` is recomputed on every pass, so compute it once into a local variable **B1**

```
DECLARE Len : INTEGER
Len <- LENGTH(Names)
FOR Index <- 1 TO Len
    OUTPUT UCASE(MID(Names, Index, 1))
NEXT Index
```

Solution 2.1

- the rewritten loop, with the declaration M1 A1

Practice 2.2 ■ 2 marks

State **two** things that make pseudocode inefficient.

Solution 2.2

Worked steps

- any two: repeating a calculation inside a loop whose answer does not change; carrying on looping after the answer is known; testing a condition that an earlier test has already settled; using a loop or a long CASE where arithmetic would do **B1** **B1**

Practice 2.3 ■ 3 marks

A program must: input a password; check whether it is valid; and display a welcome screen. State, for each of the three jobs, whether it is better written as a **procedure** or a **function**, with a reason.

Solution 2.3

Method: Where the module boundaries go — p.9

Worked steps

- input the password: a **procedure** – it performs an action and returns nothing the caller must have **B1**
- check whether it is valid: a **function** – it produces one value (TRUE/FALSE) that the rest of the algorithm uses in an IF **B1**
- display the welcome screen: a **procedure** – it does something, and there is no value to return **B1**

Practice 2.4 ■ 2 marks

In a structure chart, state what a **box** represents, and state what a small arrow pointing **up** beside a call line represents.

Solution 2.4

Method: Reading a structure chart — p.12

Worked steps

- a box represents a **module** (a procedure or function) **B1**
- an arrow pointing **up** beside a call line represents data **returned** from the lower module to the one that called it **B1**

Practice 2.5 ■ 1 mark

State what is meant by **integration testing**.

Solution 2.5

Method: Testing the pieces, then the whole — p.13

Worked steps

- modules that have already been tested individually are combined into a single sub-program, which is then tested as a whole **B1**

3

Exam-style

Exam-style 3.1 ■ 5 marks

A module counts how many values in a global array Readings of 500 integers are above a given limit.

```
FUNCTION HowMany(Limit : INTEGER) RETURNS INTEGER
  DECLARE Index : INTEGER
  Count <- 0
  FOR Index <- 1 TO 500
    IF Readings[Index] > Limit AND Readings[Index] <> -1 THEN
      IF Readings[Index] > Limit THEN
        Count <- Count + 1
      ENDIF
    ENDIF
  NEXT Index
  RETURN Count
ENDFUNCTION
```

Exam-style 3.1 (a) ■ 2 marks

State **two** ways in which this pseudocode is inefficient.

Solution 3.1 (a)

Method: What “efficient” means in this syllabus — p.4

Worked steps

the inner IF repeats a test the outer IF has already made **B1**

- `Readings[Index]` is read from the array three times in one pass, when once into a local would do; and `Count` is used without being declared **B1**

Exam-style 3.1 (b) ■ 3 marks

Rewrite the module efficiently.

Solution 3.1 (b)

Worked steps

```
FUNCTION HowMany(Limit : INTEGER) RETURNS INTEGER
  DECLARE Index, Count, ThisOne : INTEGER
  Count <- 0
  FOR Index <- 1 TO 500
    ThisOne <- Readings[Index]
    IF ThisOne > Limit AND ThisOne <> -1 THEN
      Count <- Count + 1
    ENDIF
  NEXT Index
  RETURN Count
ENDFUNCTION
```

Solution 3.1 (b)

- one test instead of two **M1**; the element read once into a local **B1**; Count declared and the return kept outside the loop **A1**

Exam-style 3.2 ■ 6 marks

A program for a library must: find a member by their card number; work out the fine owed on a late book; and print a receipt.

Break the task into **three** modules. For each one, state whether it is a procedure or a function and write its header.

Solution 3.2

Method: Where the module boundaries go — p.9

Worked steps

- find a member: a **function** – it produces one value the rest of the program uses
`B1` FUNCTION FindMember(CardNumber : STRING) RETURNS INTEGER `B1`
- work out the fine: a **function** – one value, used in an expression `B1` FUNCTION
Fine(DaysLate : INTEGER) RETURNS REAL `B1`
- print a receipt: a **procedure** – it performs an action and returns nothing `B1`
PROCEDURE PrintReceipt(MemberID : INTEGER, Amount : REAL) `B1`
- sensible names and types are accepted; a module that both finds **and** prints would lose a mark, because it does two jobs

Exam-style 3.3 ■ 4 marks

A programmer writes each module so that it uses only its parameters and its own local variables.

Exam-style 3.3 (a) ■ 2 marks

Explain why this makes a module easier to **test**.

Solution 3.3 (a)

Method: Testing the pieces, then the whole — p.13

Worked steps

everything the module uses arrives through its **interface**, so it can be called on its own with chosen test values **B1**

- nothing outside it can change its variables, so the same inputs always give the same result and a fault is traceable to that module **B1**

Exam-style 3.3 (b) ■ 2 marks

State **two** other benefits of building a program from modules.

Solution 3.3 (b)

Worked steps

any two: the same module can be reused elsewhere in the program or in another program; several programmers can work on different modules at once; a change is made in one place only; the program is easier to read because each module has one job **B1** **B1**

Exam-style 3.4 ■ 4 marks

A function is written to return the position of the first space in a string.

```
FUNCTION FirstSpace(InString : STRING) RETURNS INTEGER
  DECLARE Index, Found : INTEGER
  Found <- 0
  FOR Index <- 1 TO LENGTH(InString)
    IF MID(InString, Index, 1) = " " THEN
      IF Found = 0 THEN
        Found <- Index
      ENDIF
    ENDIF
  NEXT Index
  RETURN Found
ENDFUNCTION
```

Exam-style 3.4 ■ 4 marks

State **two** inefficiencies, and rewrite the loop so the function stops as soon as it has the answer.

Solution 3.4

Method: What “efficient” means in this syllabus — p.4

Worked steps

- the inner IF Found = 0 is only needed because the loop keeps running after the answer is known **B1**
- LENGTH(InString) is recomputed on every pass **B1**

Solution 3.4

```
FUNCTION FirstSpace(InString : STRING) RETURNS INTEGER
  DECLARE Index, Len : INTEGER
  Len <- LENGTH(InString)
  FOR Index <- 1 TO Len
    IF MID(InString, Index, 1) = " " THEN
      RETURN Index
    ENDIF
  NEXT Index
  RETURN 0
ENDFUNCTION
```

Solution 3.4

- returning immediately removes the flag and the inner test **M1**
- a final RETURN 0 for a string with no space, so a value comes back in both cases **A1**