

IBM

APL Programming Guide

First Edition (May 1978)

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APL PROGRAMMING GUIDE

VECTOR OPERATIONS

FIRST EDITION

EDITED BY

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ABSTRACT

*THIS GUIDE SUMMARIZES KEY CONCEPTS, CODING TECHNIQUES,
IDIOMS, GUIDELINES, AND TRADE-OFFS WHICH WILL HELP
THE APL PROGRAMMER TO PRODUCE EFFICIENT APL CODE.*

*KEY WORDS: APL, APLSV, PROGRAMMING TECHNIQUES,
APL/CMS, VS APL, 5100 APL*

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APL PROGRAMMING GUIDE

PREFACE

THIS GUIDE IS A COMPILATION OF KEY CONCEPTS, CODING TECHNIQUES, IDIOMS, GUIDELINES, AND TRADE-OFFS IN APL PROGRAMMING. IT IS INTENDED FOR INTERMEDIATE AND ADVANCED APL PROGRAMMERS WHO ARE FAMILIAR WITH APL SYNTAX AND OPERATIONS AS FOUND IN THE APL LANGUAGE MANUALS AND SIMILAR PUBLICATIONS. ITS GOAL IS TO SHOW GOOD IMPLEMENTATIONS OF BASIC APL DATA PROCESSING OPERATIONS.

THIS VOLUME COVERS VECTOR OPERATIONS TOPICS IN APL PROGRAMMING. IT IS DESIGNED TO BE A REFERENCE MANUAL. THE INFORMATION INCLUDED IS CATEGORIZED ACCORDING TO THE TYPE OF OPERATION PERFORMED AND THE DATA BEING PROCESSED. THE TABLE OF CONTENTS IS INTENDED TO SERVE AS THE PRIMARY MEANS FOR LOCATING THE APL CODE FOR A SPECIFIC OPERATION.

THIS GUIDE IS BASED ON EXPERIENCE WITH IBM APLSV SYSTEMS. WHERE APPROPRIATE, THE TECHNIQUES HAVE BEEN CODED SO AS NOT TO BE DEPENDENT ON ANY APL SYSTEM IMPLEMENTATION. HOWEVER, THE READER MUST DETERMINE WHETHER OR NOT CODE CHANGES ARE NECESSARY FOR EXECUTION ON ANOTHER APL SYSTEM. CERTAIN CODE IMPLEMENTATIONS MAY HAVE TO BE SPLIT INTO ADDITIONAL STATEMENTS IF THE ORDER OF EXECUTION OF OTHER APL SYSTEMS REQUIRES THIS.

IT IS THE PHILOSOPHY OF THIS GUIDE TO SHOW ONLY THE BASIC CODE NECESSARY TO PERFORM A GIVEN OPERATION. ONLY A FEW TECHNIQUES ARE ILLUSTRATED AS COMPLETELY-DEFINED APL FUNCTIONS. IT IS LEFT TO THE READER TO COMBINE THESE BASIC COMPONENTS INTO STANDARDIZED SUBROUTINES OR LARGER FUNCTIONS AS DEEMED APPROPRIATE FOR AN APPLICATION.

* * * * *

MORE THAN ONE IMPLEMENTATION OF A TECHNIQUE IS SHOWN WHEN THERE ARE SIGNIFICANT DIFFERENCES IN THE NATURE OF THE IMPLEMENTATIONS. EACH IMPLEMENTATION IS THE "BEST" ONE FOR ITS PARTICULAR APPROACH. THE ORDER IN WHICH THE IMPLEMENTATIONS ARE LISTED FOR EACH TECHNIQUE OR EACH TRADE-OFF IS BASED ON MEASUREMENTS OF THE TIME TAKEN TO PROCESS A VECTOR OF ABOUT 25 ELEMENTS. THE FASTEST IMPLEMENTATION IS SHOWN FIRST.

THE READER IS CAUTIONED, HOWEVER, THAT SUCH CHARACTERISTICS AS EXECUTION SPEED, STORAGE REQUIRED, DATA REPRESENTATION AND HANDLING, ETC., ARE DEPENDENT ON THE APL SYSTEM IMPLEMENTATION. THESE CHARACTERISTICS MAY ALSO CHANGE AS AN APL SYSTEM IS MODIFIED AND IMPROVED. THEREFORE NO EXPLICIT MEASUREMENTS OF THESE CHARACTERISTICS HAVE BEEN INCLUDED IN THIS GUIDE. READERS WHO CONSIDER THESE CHARACTERISTICS IMPORTANT IN THEIR APPLICATIONS SHOULD DETERMINE THEM FOR EACH TECHNIQUE ON THE APL SYSTEM WHICH THEY ARE USING.

APL PROGRAMMING GUIDE

PREFACE (CONTD)

EXECUTION SPEED CAN ALSO VARY WITH THE LENGTH AND NATURE OF THE VARIABLES PROCESSED. AN IMPLEMENTATION WHICH IS FASTER FOR SMALL VARIABLES MAY BE SLOWER FOR LARGE ONES. SIMILARLY, LOGICAL DATA (BITS) MAY BE HANDLED MORE SLOWLY THAN BYTE OR INTEGER DATA.

* * * * *

THE IMPLEMENTATIONS SHOWN IN THIS GUIDE ARE LARGEY NON-LOOPING SOLUTIONS USING THE POWER OF APL PRIMITIVE FUNCTIONS. THE READER SHOULD BE AWARE, HOWEVER, THAT IMPLEMENTATIONS WITH LOOPING CAN BE FASTER AND MORE EFFICIENT FOR LARGE DATA VARIABLES IN CERTAIN SITUATIONS. LOOPING WILL ALSO HELP AVOID "WS FULL" INTERRUPTIONS, ALLOWING LARGER VARIABLES TO BE PROCESSED.

SOME ALTERNATE IMPLEMENTATIONS WHICH ARE KNOWN TO BE POORER HAVE BEEN INCLUDED IN ORDER TO DOCUMENT THEIR EXISTENCE AS VARIATIONS. CERTAIN ONES FOUND IN OLDER APL FUNCTIONS REPRESENT EARLIER SOLUTIONS DEVELOPED BEFORE NEW APL PRIMITIVE FUNCTIONS WERE ADDED TO THE LANGUAGE. SOME OF THE ALTERNATE IMPLEMENTATIONS, WHILE LESS EFFICIENT FOR PERFORMING THE ENTIRE TECHNIQUE, MAY NEVERTHELESS BE BETTER IN A SPECIFIC APPLICATION WHERE THEIR INTERMEDIATE RESULTS ARE ALSO USEFUL OR ALREADY AVAILABLE FROM PREVIOUS PROCESSING. THE FINAL RESULT MIGHT BE OBTAINED FASTER BY STARTING WITH THE INTERMEDIATE DATA THAN BY PROCESSING FROM SCRATCH WITH THE FASTEST TECHNIQUE. MINOR VARIATIONS IN IMPLEMENTATION, E.G., COMPLEMENTARY OPERATIONS, ARE GENERALLY OMITTED. THE NOTATION " \leftrightarrow " MEANS "IS THE SAME AS".

EXPLANATIONS OF THE DETAIL-PROCESSING OCCURRING IN THESE TECHNIQUES ARE INCLUDED ONLY WHERE THEY WERE CONSIDERED NECESSARY. READERS WHO SEEK A SPECIFIC TECHNIQUE MAY SIMPLY COPY THE CODE AND VERIFY THE DESIRED OPERATION AND RESULTS. THOSE WHO WANT TO INCREASE THEIR GRASP AND UNDERSTANDING OF APL PROCESSING ARE ENCOURAGED TO STUDY THE CODE IN DETAIL. THIS CAN CONSIST OF FIRST WORKING IT OUT ON PAPER AND THEN EXECUTING EACH PORTION IN SEQUENCE TO EXAMINE THE RESULTS. THIS EXERCISE PROVES TO BE A VERY GOOD WAY TO UNDERSTAND AND MASTER APL SEMANTICS AND PROGRAMMING LOGIC. IT CONTRIBUTES TO THE ABILITY TO RECOGNIZE ENTIRE TECHNIQUES OR "IDIOMS" OF APL WHEN SUBSEQUENTLY READING APL PROGRAMS. SOME OF THESE TECHNIQUES ARE THEMSELVES COMBINATIONS OF SEVERAL SIMPLER TECHNIQUES.

CERTAIN BRIEF APL OPERATIONS OCCUR REPEATEDLY IN THESE TECHNIQUES. THEY CAN BE THOUGHT OF AS "KERNEL" APL OPERATIONS AND ARE IDENTIFIED AS SUCH IN THE TEXT. WHILE THEY ARE NOT NECESSARILY USED TO PRODUCE FINAL RESULTS IN THEMSELVES, THEY FORM THE BASIS FOR MANY OTHER MORE COMPLEX TECHNIQUES. THEREFORE THEY ARE WORTH RECOGNIZING AND LEARNING.

APL PROGRAMMING GUIDE

PREFACE (CONTD)

MANY OPERATIONS ARE SHOWN WITH A GENERALIZED TEST VARIABLE, E.G., "Q", AND THEY MAY BE USABLE FOR EITHER NUMERIC OR CHARACTER DATA. IN APPLICATIONS WHERE ONLY ONE KIND OF DATA IS PROCESSED, THE SPECIFIC DATA ELEMENTS, E.G., 0 OR ' ', MAY BE SUBSTITUTED IN THE EXPRESSION RATHER THAN ASSIGNING THEM TO THE VARIABLE.

WHEREVER POSSIBLE AND APPROPRIATE, THE IMPLEMENTATIONS OF THESE TECHNIQUES ARE CODED TO EXECUTE THE SAME REGARDLESS OF THE VALUE OF THE INDEX ORIGIN \square_{IO} . THIS IS DONE TO INCREASE THE USABILITY OF THE TECHNIQUES. HOWEVER IT FREQUENTLY MAKES THE APL CODE MORE DIFFICULT TO READ AND MORE CUMBERSOME. IF A TECHNIQUE IS TO BE EXECUTED IN AN ENVIRONMENT WITH AN UNCHANGING INDEX ORIGIN, IT IS SUGGESTED THAT THE READER SUBSTITUTE THE ORIGIN VALUE FOR \square_{IO} WHERE IT APPEARS IN THE CODE AND THEN SIMPLIFY THE APL EXPRESSIONS WHICH RESULT.

* * * * *

THE PAGES OF THIS GUIDE HAVE BEEN FORMATTED AND GENERATED BY EXECUTION OF APL FUNCTIONS. IN ALMOST ALL CASES THE RESULTS SHOWN FOR EACH OPERATION HAVE BEEN GENERATED BY ACTUALLY EXECUTING THE ILLUSTRATED APL CODE. THE CODE FOR ALTERNATE IMPLEMENTATIONS HAS BEEN EXECUTED AND THE RESULTS COMPARED WITH THE MAIN ILLUSTRATION. CODE WHICH IS AFFECTIONED BY THE INDEX ORIGIN HAS BEEN EXECUTED IN BOTH ORIGINS AND THE RESULTS COMPARED (WITH ANY NECESSARY ADJUSTMENTS). THEREFORE THE CORRECTNESS OF THE CODE SHOWN FOR EACH TECHNIQUE HAS BEEN VERIFIED IN THE PROCESS OF GENERATING THESE PAGES.

READERS WHO KNOW OF OTHER "BETTER" IMPLEMENTATIONS OF ANY TECHNIQUE OR WHO DETERMINE IMPROVEMENTS TO ANY IMPLEMENTATIONS SHOWN IN THIS GUIDE ARE REQUESTED TO SEND THIS INFORMATION TO THE EDITOR. CONTRIBUTIONS AND SUGGESTIONS FOR ADDITIONAL TECHNIQUES ARE ALSO WELCOME.

THE EDITOR IS INDEBTED TO MANY APL PROGRAMMERS, BOTH KNOWN AND UNKNOWN, FOR THE CODE WHICH HAS BEEN INCLUDED IN THIS GUIDE. SPECIAL APPRECIATION IS EXTENDED TO THE REVIEWERS, WHO CONTRIBUTED IMPROVEMENTS TO THE CODE, THE TEXT, AND THE FORMAT OF THIS GUIDE.

CERTAIN MATERIAL IDENTIFIED BY FOOTNOTES HAS BEEN ADAPTED FROM THE PUBLICATIONS LISTED BELOW. SOME OF THE MATERIAL IS UNCHANGED EXCEPT FOR VARIABLE NAMES AND APL SYSTEM DIFFERENCES.

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APL PROGRAMMING GUIDE

PREFACE (CONTD)

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APL PROGRAMMING GUIDE

VECTOR OPERATIONS -- TABLE OF CONTENTS

CREATING A VECTOR V	1
BY CATEGORIZATION	1
CATENATING UNIQUE ELEMENTS Q TO V AND INCREMENTING COUNTERS C	3
BY ASSIGNMENT AND INDEXING	4
BY RESHAPING ANOTHER VARIABLE W	5
GENERATING A VECTOR USING A LOGICAL VECTOR AND A SCALAR Q	6
GENERATING A VECTOR OF INDICES	7
IN FIELDS OF WIDTHS W	7
GENERATING THE "X"TH AXIS INDICES I FOR ALL ELEMENTS OF ARRAY A, CORRESPONDING TO RAVEL-A (.A)	8
IN INCREASING-DECREASING SEQUENCE, WITH LENGTH L	10
IN INCREASING-DECREASING SEQUENCE, WITH LENGTH L, AND WITH MAXIMUM VALUE K	10
GENERATING A VECTOR WITH A RANGE OF NUMBERS	11
SUCCESSIVE INTEGERS FROM J TO K	11
SUCCESSIVE REAL NUMBERS FROM J TO K INCREMENTING BY D	11
R SUCCESSIVE REAL NUMBERS STARTING WITH N AND INCREMENTING BY D	12
GENERATING A LOGICAL (BOOLEAN) VECTOR	13
WITH K LEADING 1'S AND LENGTH L	13
WITH K TRAILING 1'S AND LENGTH L	13
DEFINING THE FIELD PARTITION P OF V	14
WHEN THERE ARE NO FIELD DELIMITERS	14
WHEN THE FIELD DELIMITER IS Q	18
IN FIELDS OF WIDTHS W, ALTERNATING 1'S AND 0'S	19
EXPANDING / INSERTING ELEMENTS INTO A VECTOR V	20
INSERTING K ELEMENTS Q BEFORE/AFTER EACH ELEMENT OF V	20
INSERTING K ELEMENTS Q BEFORE/AFTER THE ELEMENTS WITH INDICES I	22
INSERTING ELEMENT Q IN WIDTHS W BEFORE/AFTER THE ELEMENTS WITH INDICES I	24
EXPANDING FIELDS WITH DIFFERENT WIDTHS W TO FIELDS OF THE SAME WIDTH L	26
INSERTING ELEMENT Q AFTER EVERY "K"TH ELEMENT OF V	27
INSERTING A STRING S AFTER THE ELEMENT WITH INDEX I	28
EXPANDING V TO LENGTH L	29
PADDING WITH THE PAD-ELEMENT (0 OR BLANK)	29
PADDING WITH THE LAST ELEMENT	29
TESTING THE ELEMENTS IN A VECTOR V	30
DETERMINING IF ELEMENT Q OCCURS IN V	30
DETERMINING IN WHICH FIELD OF V AN ELEMENT Q OCCURS	31
COUNTING THE NUMBER OF OCCURRENCES N OF ELEMENTS Q IN V	33
PERFORMING RELATIONAL TESTS ALONG V	34
DETERMINING IF ALL THE ELEMENTS OF V ARE UNIQUE	35

APL PROGRAMMING GUIDE

VECTOR OPERATIONS -- TABLE OF CONTENTS (CONTD)

SELECTING ELEMENTS OF A VECTOR V	36
SELECTING ELEMENTS THAT SATISFY A TEST	36
SELECTING ELEMENTS P WHICH ARE BETWEEN PAIRED DELIMITERS D ..	37
SELECTING ELEMENTS P WHICH ARE OUTSIDE PAIRED DELIMITERS D ..	39
SELECTING SUBSTRING S WITH STARTING INDEX I AND LENGTH L ..	41
SELECTING LEFT AND RIGHT FIELDS OF V DELIMITED BY THE ELEMENT Q	42
SELECTING FIELD N OF V	43
FINDING INDICES OF ELEMENTS OF A VECTOR V	45
FINDING THE INDICES OF ELEMENTS THAT SATISFY A TEST	45
FINDING THE INDEX OF THE 1ST OCCURRENCE OF ELEMENTS Q	46
FINDING THE INDEX OF THE LAST OCCURRENCE OF ELEMENTS Q	47
FINDING THE INDICES I OF THE SMALLEST AND LARGEST ELEMENTS ..	48
FINDING THE STARTING INDICES I OF OCCURRENCES OF A PATTERN OF ELEMENTS	49
FINDING ALL OCCURRENCES OF A SUBSTRING S	49
FINDING ALL OCCURRENCES OF A WORD S	50
FINDING THE BOUNDARY INDICES OF THE FIELDS OF V	51
WHEN THERE ARE NO FIELD DELIMITERS	51
WHEN THE FIELD DELIMITER IS Q	53
SHIFTING A VECTOR V	54
SHIFTING N POSITIONS WITHOUT CHANGING THE LENGTH OF V	54
WITH WRAP-AROUND (ROTATING)	54
WITHOUT WRAP-AROUND	54
CENTERING V	55
WHEN THE FILL-ELEMENT IS Q	55
WITHIN A FIELD OF PAD-ELEMENTS OF WIDTH W	56
COMPRESSING THE FILL-ELEMENT Q TO THE SIDES	57
RIGHT-JUSTIFYING V	58
WHEN THE FILL-ELEMENT IS Q	58
WITHIN A FIELD OF PAD-ELEMENTS OF WIDTH W	60
COMPRESSING THE FILL-ELEMENT Q LEFT	61
LEFT-JUSTIFYING V	62
WHEN THE FILL-ELEMENT IS Q	62
WITHIN A FIELD OF PAD-ELEMENTS OF WIDTH W	64
COMPRESSING THE FILL-ELEMENT Q RIGHT	65
REVERSING THE POSITIONS OF THE ELEMENTS OF V	66
REVERSING THE ELEMENTS WITH INDICES I	66
REVERSING THE ELEMENTS WITHIN EACH FIELD OF V	67
SORTING A VECTOR V	68
SORTING A NUMERIC VECTOR	68
IN ASCENDING ORDER	68
IN DESCENDING ORDER	68

APL PROGRAMMING GUIDE

VECTOR OPERATIONS -- TABLE OF CONTENTS (CONTD)

SORTING A VECTOR V (CONTD)

IN EITHER ASCENDING OR DESCENDING ORDER	68
SORTING THE ELEMENTS OF V WITHIN THE FIELDS OF V	69
IN ASCENDING ORDER	69
IN DESCENDING ORDER	70
DETERMINING THE RANK-ORDER R OF THE ELEMENTS OF V	71
ASCENDING RANK-ORDER	71
DESCENDING RANK-ORDER	71
SORTING A CHARACTER VECTOR	72
MOVING CHARACTERS NOT IN THE SORT SEQUENCE TO END OF V	72
DELETING CHARACTERS NOT IN THE SORT SEQUENCE	73
MERGING 2 NUMERIC VECTORS IN ASCENDING ORDER	74
MERGING 2 VECTORS USING THE PATTERN IN LOGICAL VECTOR L	75
MERGING 2 VECTORS OF SAME LENGTH IN ALTERNATING POSITIONS	76
COMPUTING VALUES FROM A VECTOR V	77
DETERMINING THE WIDTHS W OF THE FIELDS OF V	77
WHEN THERE ARE NO FIELD DELIMITERS	77
WHEN THE FIELD DELIMITER IS Q	77
SUMMING SETS OF ELEMENTS OF V	78
SETS OF ELEMENTS SORTED INTO FIELDS	78
SETS OF ELEMENTS NOT IN FIELDS	79
DETERMINING THE PAIRWISE DIFFERENCES D IN V	80
COMPUTING THE AVERAGE OF THE VALUES IN V	81
PERFORMING ARITHMETIC SCAN OPERATIONS ON V	82
PERFORMING LOGICAL SCAN OPERATIONS ON V	83
REPLACING ELEMENTS OF A VECTOR V	85
REPLACING ELEMENTS SELECTED BY A TEST	85
WITH ELEMENT Q	85
WITH THE PAD-ELEMENT (0 OR BLANK)	87
REPLACING MULTIPLE OCCURRENCES OF AN OLD SUBSTRING OS WITH A NEW SUBSTRING NS	88
DELETING ELEMENTS FROM A VECTOR V	89
DELETING ALL OCCURRENCES OF ELEMENT Q	89
DELETING ALL LEADING OCCURRENCES OF ELEMENT Q	90
DELETING ALL.TRAILING OCCURRENCES OF ELEMENT Q	91
DELETING LEADING AND.TRAILING OCCURRENCES OF ELEMENT Q	92
DELETING REDUNDANT OCCURRENCES OF ELEMENT Q	93
DELETING REDUNDANT OCCURRENCES OF ALL ELEMENTS	94
DELETING LEADING, TRAILING, AND REDUNDANT OCCURRENCES OF ELEMENT Q	95
DELETING THE ELEMENTS WITH INDICES I	96
DELETING A SUBSTRING WITH STARTING INDEX I AND LENGTH L	97
DELETING DUPLICATE OCCURRENCES OF ALL ELEMENTS	98

CREATING A VECTOR V

BY CATENATION

TYPE 1: CATENATING INDIVIDUAL ELEMENTS

- Ⓐ INITIALIZE TO AN "EMPTY" VECTOR

$V \leftarrow 10$ OR $V \leftarrow ''$ OR $V \leftarrow 0 \rho \dots$

- Ⓐ ADD ELEMENTS BY CATENATION

$V \leftarrow V, 45 78 23$

- Ⓐ USE THIS METHOD WHEN THE FINAL SIZE OF V IS UNKNOWN

- Ⓐ CAUTION: CATENATION REQUIRES THAT $\square WA >$ THE STORAGE TAKEN UP BY "V". WHEN $\square WA$ BECOMES $<$, A "WS FULL" WILL OCCUR.

TYPE 2: CATENATING SEVERAL VECTORS

- Ⓐ GENERATE SEPARATE "PARTIAL"-VECTORS

$T \leftarrow 'FINAL SUMMARY REPORT OF ANNUAL SALES'$
 $D \leftarrow 'DECEMBER 31, 19', 20 \rho Y$
 $BR \leftarrow 'BRANCH OFFICE NO.', \rho N$

- Ⓐ CATEenate VECTORS TO FORM LONGER VECTOR

$HDR \leftarrow T, ' -- ', BR, ' -- ', D$

- Ⓐ USE THIS METHOD WHEN FINAL VECTOR WOULD BE TOO LONG
- Ⓐ FOR ONE FUNCTION STATEMENT. THIS ALSO ALLOWS THE THE INDIVIDUAL VECTORS TO BE USED IN MORE THAN ONE STATEMENT.

(CONT'D ON NEXT PAGE)

CREATING A VECTOR V

BY CATENATION (CONTD)

**TYPE 3: MANUALLY ENTERING A VECTOR WHERE THE DATA EXCEEDS
THE TERMINAL INPUT LINE LENGTH**

- Ⓐ CATEenate a "□" AT THE END OF EACH LINE WHICH IS
- Ⓐ TO BE CONTINUED

V←2.3 9.7 6.2 5.8 ... 43.79, □

□:

93.7 105.2 125.3 ... 155.1, □

□:

... ETC.

- Ⓐ CHARACTER INPUT MUST BE TYPED WITHIN QUOTES

CREATING A VECTOR V

CATENATING UNIQUE ELEMENTS Q TO V AND INCREMENTING COUNTERS C

a CATENATE THE ELEMENTS ONLY IF THEY DON'T OCCUR IN V

$V \leftarrow V, (L \leftarrow \sim Q \in V) / Q$ **

a INCREMENT THE CORRESPONDING COUNTER IN C FOR EACH
a ELEMENT

$C \leftarrow (C, L / 0) + V \in Q$ **

a $\rho V \leftrightarrow \rho C$
a $C[I]$ IS THE COUNT OF OCCURRENCES OF $V[I]$

EXAMPLE: $V \leftarrow 'MECRVKID'$
 $C \leftarrow 2 5 2 1 1 2 3 1$
 $Q \leftarrow 'BASED'$

RESULT: $V: MECRVKIDBAS$
 $C: 2 6 2 1 1 2 3 2 1 1 1$

a IF ANY ELEMENTS IN Q OCCUR MORE THAN ONCE:

$V \leftarrow V, (L \leftarrow \sim U \in V) / U \leftarrow ((\iota \rho Q) = Q \iota Q) / Q$

$C \leftarrow (C, L / 0) ++ / V \circ . = Q$

EXAMPLE: $Q \leftarrow 'MISSISSIPPI IS THE MAGNOLIA STATE'$

RESULT: $V: MECRVKIDBASP THGNOL$
 $C: 4 8 2 1 1 2 9 2 1 4 7 2 4 3 1 1 1 1 1$

** ADAPTED FROM (1) THE APL IDIOM LIST

CREATING A VECTOR V

BY ASSIGNMENT AND INDEXING

- Ⓐ FIRST ASSIGN "N" FILL-ELEMENTS TO THE VECTOR, E.G.,
- Ⓐ PAD-ELEMENTS (0 OR BLANK); N = A POSITIVE INTEGER

V \leftarrow N ρ 0

- Ⓐ NOTE: N ρ 0 PRODUCES 1-BIT ELEMENTS. THESE WILL INCREASE TO INTEGER OR FLOATING POINT ELEMENTS WHEN THE FIRST VALUE \neq 0 OR 1 IS ASSIGNED.

- Ⓐ INITIALIZE INDEXING VARIABLE

PTR \leftarrow 0 [IO \leftarrow 1]

- Ⓐ STORE ELEMENTS IN VECTOR BY INDEXING, CHECKING FOR END OF VECTOR

$\rightarrow(N < PTR \leftarrow PTR + 1) / END$
V[PTR] \leftarrow 45

- Ⓐ ALTERNATIVELY

$\rightarrow(N < -1 + I \leftarrow PTR + 1 K) / END$
V[I] \leftarrow 1 2 3 ... K [IO \leftarrow 1]
PTR \leftarrow PTR+K

- Ⓐ USE THIS METHOD IF THE FINAL SIZE OF VECTOR (OR AN UPPER LIMIT ON THE SIZE) IS KNOWN
- Ⓐ CAUTION: IF THE STORAGE TAKEN UP BY "V" $>$ $\square WA$, NO OPERATION CAN BE PERFORMED WHICH WOULD DUPLICATE "V" (WILL RESULT IN A "WS FULL")

CREATING A VECTOR V

BY RESHAPING ANOTHER VARIABLE W

$V \leftarrow N \rho W$

- a W MAY BE AN ARRAY OF ANY RANK (0, 1, 2, 3, ...)
- a N MUST BE AN INTEGER ≥ 0

EXAMPLE: $W \leftarrow ' \square '$
 $N \leftarrow 10$

RESULT: $\square \square \square \square \square \square \square \square \square$

EXAMPLE: $W \leftarrow 'ABCD'$
 $N \leftarrow 13$

RESULT: ABCDABCDABCDABCD

EXAMPLE: $W \leftarrow 2 3 4 \rho 1 0 0 1 0$
 $N \leftarrow 17$

RESULT: 1 0 0 1 0 1 0 0 1 0 1 0 0 1 0 1 0

- a TO REPLICATE A VECTOR W N-TIMES:

$V \leftarrow (N \times \rho W) \rho W$

- a N MUST BE AN INTEGER ≥ 0

EXAMPLE: $W \leftarrow '1234'$
 $N \leftarrow 4$

RESULT: 1234123412341234

CREATING A VECTOR V

GENERATING A VECTOR USING A LOGICAL VECTOR AND A SCALAR Q

`V←(LOGICAL VECTOR)\Q`

A PAD-ELEMENTS (0 OR BLANK) OCCUPY THE 0-BIT POSITIONS

EXAMPLE: UNDERLINING A HEADING (REPLACE Q WITH '—')

`HDR←'THIS IS A HEADING'
V←(HDR≠' ')\'—'`

RESULT: ----- - - - - -

EXAMPLE: `L←1 1 0 0 1 1 0 0 1 1 0 0 1 1 0 0
V←L\'o'`

RESULT:

CREATING A VECTOR V

GENERATING A VECTOR OF INDICES

IN FIELDS OF WIDTHS W

```
V←(+/W)ρ0  
V[+\\(1□IO), -1+W]←1  
V←+\\V
```

EXAMPLE: W←2 2 4 1

RESULT: 1 1 2 2 3 3 3 3 4 [□IO←1]

A ALTERNATE IMPLEMENTATIONS:

```
V←□IO++\\(1+/W)ε□IO++\\W
```

```
V←□IO++/(1+/W)◦ . ≥□IO++\\W
```

A TO GENERATE A VECTOR OF THE ELEMENTS IN VECTOR "X",
A CODE: X[V]

EXAMPLE: X←'Δc*⇒∇'
W←3 1 1 2 3

RESULT: ΔΔΔc*⇒∇∇∇

CREATING A VECTOR V

GENERATING A VECTOR OF INDICES

GENERATING THE "X"TH AXIS INDICES I FOR ALL ELEMENTS OF ARRAY A, CORRESPONDING TO RAVEL-A (,A)

$R \leftarrow (\sim \square I O) + X - \rho \rho A$
 $I \leftarrow , (R \phi \rho \rho A) \& (R \phi \rho A) \rho i (\rho A)[X]$

Ⓐ THIS CAN BE SIMPLIFIED FOR ARRAYS OF RANK 1 OR 2:

Ⓐ RANK 1 (= VECTOR): $I \leftarrow \rho A$

Ⓐ NOTE: THIS IS A "KERNEL" APL OPERATION

Ⓐ RANK 2 (= MATRIX):

Ⓐ ROW INDICES (X=1): $I \leftarrow , \& (\phi \rho A) \rho i 1 \uparrow \rho A$

Ⓐ COL INDICES (X=2): $I \leftarrow , (\rho A) \rho i 1 \uparrow \rho A$

Ⓐ NOTE: FOR RANK ≥ 3 , THE EXPRESSION FOR THE LAST AXIS (COLUMNS) IS THE SAME AS SHOWN ABOVE FOR RANK 2.

EXAMPLE: $A \leftarrow 2 3 2 \rho i 12$

1 2
3 4
5 6

7 8
9 10
11 12

,
 A
1 2 3 4 5 6 7 8 9 10 11 12

RESULT: CORRESPONDING PLANE INDICES ($X \leftarrow 1$): $[\square I O \leftarrow 1]$
1 1 1 1 1 1 2 2 2 2 2 2

CORRESPONDING ROW INDICES ($X \leftarrow 2$):
1 1 2 2 3 3 1 1 2 2 3 3

CORRESPONDING COLUMN INDICES ($X \leftarrow 3$):
1 2 1 2 1 2 1 2 1 2 1 2

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CREATING A VECTOR V

GENERATING A VECTOR OF INDICES

GENERATING THE "X"TH AXIS INDICES I FOR ALL ELEMENTS OF ARRAY A, CORRESPONDING TO RAVEL-A (,A) (CONTD)

A ALTERNATE IMPLEMENTATION:

$I \leftarrow \square IO + ((\rho A) \tau (1 \times / \rho A) - \square IO)[X;]$

A NOTE: THIS IMPLEMENTATION GENERATES INDICES FOR ALL THE AXES AT ONE TIME

CREATING A VECTOR V

GENERATING A VECTOR OF INDICES

IN INCREASING-DECREASING SEQUENCE, WITH LENGTH L

$V \leftarrow (1^H), \phi_{1 \leq H \leq L+2}$

EXAMPLE: $L \leftarrow 8$

RESULT: 1 2 3 4 4 3 2 1 [$\square IO \leftarrow 1$]

EXAMPLE: $L \leftarrow 13$

RESULT: 0 1 2 3 4 5 6 5 4 3 2 1 0 [$\square IO \leftarrow 0$]

NOTE: IF $H \leftarrow$ A DIMENSION OF A MATRIX M, V CAN BE
USED TO EXPAND M SYMMETRICALLY, I.E., $M[V;]$ FOR
ROW SYMMETRY, $M[;V]$ FOR COLUMN SYMMETRY

IN INCREASING-DECREASING SEQUENCE, WITH LENGTH L,
AND WITH MAXIMUM VALUE K

$V \leftarrow K \leftarrow (1^H), \phi_{1 \leq H \leq L+2}$

EXAMPLE: $L \leftarrow 12$
 $K \leftarrow 3$

RESULT: 1 2 3 3 3 3 3 3 3 2 1 [$\square IO \leftarrow 1$]

CREATING A VECTOR V

GENERATING A VECTOR WITH A RANGE OF NUMBERS

SUCCESSIVE INTEGERS FROM J TO K

$V \leftarrow J + (xK - J) \times (1 + |K - J|) - \square IO$

EXAMPLE: $J \leftarrow 7$
 $K \leftarrow -2$

RESULT: 7 6 5 4 3 2 1 0 -1 -2

SUCCESSIVE REAL NUMBERS FROM J TO K INCREMENTING BY D

$V \leftarrow J + (D \times xK - J) \times (1 + |L(K - J) \div D|) - \square IO$

$\text{where } J \text{ AND } K \text{ ARE ANY REAL NUMBERS; } D \text{ REAL AND } > 0$

EXAMPLE: $J \leftarrow 1.4$
 $K \leftarrow 8.2$
 $D \leftarrow .7$

RESULT: 1.4 2.1 2.8 3.5 4.2 4.9 5.6 6.3 7 7.7

(CONT'D ON NEXT PAGE)

CREATING A VECTOR V

GENERATING A VECTOR WITH A RANGE OF NUMBERS (CONTD)

R SUCCESSIVE REAL NUMBERS STARTING WITH N AND INCREMENTING BY D

$$V \leftarrow N + D \times (\text{1}R) - \square IO$$

A R IS ANY INTEGER ≥ 0 ; N AND D ARE ANY REAL NUMBERS

EXAMPLE: $R \leftarrow 10$
 $N \leftarrow 0$
 $D \leftarrow .1$

RESULT: 0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9

A SPECIAL CASE IMPLEMENTATIONS, FOR INTEGER N
A AND D = 1:

$$V \leftarrow (N - \square IO) + \text{1}R$$

$$V \leftarrow (N - \square IO) + \text{1}R + N - \square IO \quad **$$

EXAMPLE: $R \leftarrow 8$
 $N \leftarrow 13$

RESULT: 13 14 15 16 17 18 19 20

** ADAPTED FROM (3) USE AND MISUSE OF APL

CREATING A VECTOR V

GENERATING A LOGICAL (BOOLEAN) VECTOR

WITH K LEADING 1'S AND LENGTH L

$$V \leftarrow L \uparrow K \rho 1$$

EXAMPLE: $L \leftarrow 12$
 $K \leftarrow 5$

RESULT: 1 1 1 1 1 0 0 0 0 0 0 0

a ALTERNATE IMPLEMENTATION:

$$V \leftarrow (K - \sim \square I O) \geq_1 L$$

WITH K TRAILING 1'S AND LENGTH L

$$V \leftarrow (-L) \uparrow K \rho 1$$

RESULT: 0 0 0 0 0 0 0 1 1 1 1 1

a ALTERNATE IMPLEMENTATION:

$$V \leftarrow (L - K + \sim \square I O) <_1 L$$

CREATING A VECTOR V

GENERATING A LOGICAL (BOOLEAN) VECTOR

DEFINING THE FIELD PARTITION P OF V

- Ⓐ $\rho P \leftrightarrow \rho V$
- Ⓐ $P[I] = 1$ WHERE $V[I]$ IS THE FIRST (OR LAST) ELEMENT
OF A FIELD; OTHERWISE $P[I] = 0$
- Ⓐ NOTE: THIS VECTOR "P" IS REQUIRED WHEN PERFORMING
CERTAIN OTHER OPERATIONS ON FIELDS OF V

WHEN THERE ARE NO FIELD DELIMITERS

TYPE 1: FOR K FIELDS WITH SAME WIDTH W

FIRST: $P \leftarrow (K \times W) \rho W \uparrow 1$

LAST: $P \leftarrow (K \times W) \rho (-W) \uparrow 1$

- Ⓐ NOTE: THIS IS A "KERNEL" APL OPERATION

EXAMPLE: $K \leftarrow 5$
 $W \leftarrow 3$

RESULT: FIRST: 1 0 0 1 0 0 1 0 0 1 0 0 1 0 0
LAST: 0 0 1 0 0 1 0 0 1 0 0 1 0 0 1

- Ⓐ ALTERNATE IMPLEMENTATIONS:

FIRST: $P \leftarrow (K \times W) \rho 1, (W-1) \rho 0$

LAST: $P \leftarrow (K \times W) \rho ((W-1) \rho 0), 1$

- Ⓐ NOTE: THIS FIELD PARTITION CAN BE USED WHEN
PROCESSING A $K \times W$ MATRIX RAVELED AS A VECTOR

(CONT'D ON NEXT PAGE)

CREATING A VECTOR V

GENERATING A LOGICAL (BOOLEAN) VECTOR

DEFINING THE FIELD PARTITION P OF V (CONTD)

WHEN THERE ARE NO FIELD DELIMITERS (CONTD)

TYPE 2: FROM A VECTOR I OF INDEX NUMBERS OF THE
1ST ELEMENTS OF EACH FIELD

FIRST: $P \leftarrow (\downarrow \rho V) \in I$

LAST: $P \leftarrow \downarrow \phi(\downarrow \rho V) \in I$

A NOTE: THIS IS A "KERNEL" APL OPERATION

EXAMPLE: $V \leftarrow \downarrow 10$
 $I \leftarrow 1 4 5 9$ [] $\square I O \leftarrow 1$

RESULT: $FIRST: 1 0 0 1 1 0 0 0 1 0$
 $LAST: 0 0 1 1 0 0 0 1 0 1$

A NOTE: " $P \leftarrow (\downarrow \rho V) \in I$ " IS ALSO VALID FOR A VECTOR V
WITH FIELD DELIMITERS

(CONTD ON NEXT PAGE)

CREATING A VECTOR V

GENERATING A LOGICAL (BOOLEAN) VECTOR

DEFINING THE FIELD PARTITION P OF V (CONT'D)

WHEN THERE ARE NO FIELD DELIMITERS (CONT'D)

TYPE 3: FROM A VECTOR OF FIELD-WIDTHS W,
WHERE $\rho V \leftrightarrow +/W$

FIRST: $P \leftarrow (_+/W) \epsilon + \setminus \square I O, W$

LAST: $P \leftarrow (_+/W) \epsilon (+\setminus W) - \sim \square I O$

EXAMPLE: $W \leftarrow 3 \ 1 \ 4 \ 2$

RESULT: $FIRST: 1 \ 0 \ 0 \ 1 \ 1 \ 0 \ 0 \ 0 \ 1 \ 0$
 $LAST: 0 \ 0 \ 1 \ 1 \ 0 \ 0 \ 0 \ 1 \ 0 \ 1$

A ALTERNATE IMPLEMENTATIONS:

FIRST: $B \leftarrow (G \times \rho W) \rho (G \leftarrow \lceil /W) \uparrow 1$
 $P \leftarrow (, W \circ . > (_G) - \square I O) / B$

LAST: $B \leftarrow (G \times \rho W) \rho (-G \leftarrow \lceil /W) \uparrow 1$
 $P \leftarrow (, W \circ . > \phi (_G) - \square I O) / B$

(CONT'D ON NEXT PAGE)

CREATING A VECTOR V

GENERATING A LOGICAL (BOOLEAN) VECTOR

DEFINING THE FIELD PARTITION P OF V (CONTD)

WHEN THERE ARE NO FIELD DELIMITERS (CONTD)

TYPE 4: *FROM A VECTOR OF FIELDS OF IDENTICAL ELEMENTS*

FIRST: $P \leftarrow 1, (1 \downarrow V) \neq -1 \downarrow V$

LAST: $P \leftarrow ((1 \downarrow V) \neq -1 \downarrow V), 1$

• NOTE: THIS IS A "KERNEL" APL OPERATION

• NOTE: MAY HAVE TO SORT V FIRST TO PRODUCE THE FIELDS

EXAMPLE: $V \leftarrow 'BBDCCCAC'$

RESULT: *FIRST:* 1 0 1 0 0 0 1 0 0 1

LAST: 0 1 0 0 0 1 0 0 1 1

• ALTERNATE IMPLEMENTATIONS:

FIRST: $P \leftarrow V \neq -1 \downarrow (1 \uparrow 0 \rho V), V$

LAST: $P \leftarrow V \neq 1 \downarrow V, 1 \uparrow 0 \rho V$

• THESE CAN BE SIMPLIFIED AS FOLLOWS:

NUMERIC V *CHARACTER V*

FIRST: $P \leftarrow V \neq -1 \downarrow 0, V$ $P \leftarrow V \neq -1 \downarrow ' ', V$

LAST: $P \leftarrow V \neq 1 \downarrow V, 0$ $P \leftarrow V \neq 1 \downarrow V, '$

(CONTD ON NEXT PAGE)

CREATING A VECTOR V

GENERATING A LOGICAL (BOOLEAN) VECTOR

DEFINING THE FIELD PARTITION P OF V (CONTD)

WHEN THERE ARE NO FIELD DELIMITERS (CONTD)

TYPE 4: (CONTD)

- CAUTION: 1ST AND LAST ELEMENTS OF V MUST BE
- DIFFERENT TO USE THE FOLLOWING IMPLEMENTATIONS

FIRST: $P \leftarrow V \neq -1 \phi V$

LAST: $P \leftarrow V \neq 1 \phi V$

WHEN THE FIELD DELIMITER IS Q

FIRST: $P \leftarrow S > -1 + 0, S \leftarrow V \neq Q$

LAST: $P \leftarrow S > 1 + (S \leftarrow V \neq Q), 0$

- NOTE: EMPTY FIELDS ARE ELIMINATED FROM THE PARTITION

EXAMPLE: $V \leftarrow 'ALPHA, PHI, , BETA'$
 $Q \leftarrow ', '$

RESULT: $FIRST: 0 \ 1 \ 0 \ 0 \ 0 \ 0 \ 0 \ 1 \ 0 \ 0 \ 0 \ 0 \ 1 \ 0 \ 0 \ 0$
 $LAST: \ 0 \ 0 \ 0 \ 0 \ 0 \ 1 \ 0 \ 0 \ 0 \ 1 \ 0 \ 0 \ 0 \ 0 \ 0 \ 1$

- NOTE: TO DELETE THE FIELD DELIMITERS FROM V AND P
- FOR OTHER PROCESSING, USE:

$V \leftarrow S / V$ OR $V \leftarrow (V \neq Q) / V$

$P \leftarrow S / P$ OR $P \leftarrow (V \neq Q) / P$

CREATING A VECTOR V

GENERATING A LOGICAL (BOOLEAN) VECTOR

IN FIELDS OF WIDTHS W, ALTERNATING 1'S AND 0'S

TYPE 1: K FIELDS WITH SAME WIDTH W

$$V \leftarrow (K \times W) \rho (W \times 2) \uparrow W \rho 1$$

Ⓐ NOTE: TO START WITH 0'S, CODE: "...(-W×2)..."

EXAMPLE: $K \leftarrow 5$
 $W \leftarrow 3$

RESULT: 1 1 1 0 0 0 1 1 1 0 0 0 1 1 1

TYPE 2: FROM A VECTOR OF FIELD-WIDTHS W,
WHERE $\rho V \leftrightarrow +/W$

$$V \leftarrow \neq \backslash (1 + /W) \epsilon + \backslash \square IO, W$$

Ⓐ NOTE: TO START WITH 0'S, CODE: $\sim V$

EXAMPLE: $W \leftarrow 5 2 3 1 4$

RESULT: 1 1 1 1 1 0 0 1 1 1 0 1 1 1 1

Ⓐ NOTE: THIS IS A " \neq SCAN" OPERATION PERFORMED ON A
LOGICAL VECTOR DEFINING THE 1ST ELEMENTS OF THE
FIELD PARTITION OF V (SEE PREVIOUS TECHNIQUE).

Ⓐ ALTERNATE IMPLEMENTATION:

$$B \leftarrow (G \times \rho W) \rho (G \times 2) \uparrow (G \leftarrow \lceil /W) \rho 1$$
$$V \leftarrow (, W \circ . > (1 G) - \square IO) / B$$

Ⓐ NOTE: TO START WITH 0'S, CODE: "...(-G×2)..."

EXPANDING / INSERTING ELEMENTS INTO A VECTOR V

INSERTING K ELEMENTS Q BEFORE/AFTER EACH ELEMENT OF V

TYPE 1: INSERTING PAD-ELEMENTS (0 OR BLANK)

AFTER: $V \leftarrow , V, ((\rho V), K) \rho Q$ [$Q \leftarrow 0$ OR $Q \leftarrow ' '$]

BEFORE: $V \leftarrow , (((\rho V), K) \rho Q), V$

EXAMPLE: INSERTING ZEROES

$V \leftarrow 15$

$K \leftarrow 2$

$Q \leftarrow 0$

RESULT: AFTER: 1 0 0 2 0 0 3 0 0 4 0 0 5 0 0
BEFORE: 0 0 1 0 0 2 0 0 3 0 0 4 0 0 5

A ALTERNATE IMPLEMENTATIONS:

AFTER: $V \leftarrow , ((\rho V), K+1) \uparrow ((\rho V), 1) \rho V$

BEFORE: $V \leftarrow , ((\rho V), -K+1) \uparrow ((\rho V), 1) \rho V$

AFTER: $V \leftarrow (((K+1) \times \rho V) \rho (K+1) \uparrow 1) \setminus V$

BEFORE: $V \leftarrow (((K+1) \times \rho V) \rho (-K+1) \uparrow 1) \setminus V$

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EXPANDING / INSERTING ELEMENTS INTO A VECTOR V

INSERTING K ELEMENTS Q BEFORE/AFTER EACH ELEMENT OF V (CONTD)

TYPE 2: INSERTING ANY OTHER ELEMENT Q

AFTER: $V \leftarrow, V, ((\rho V), K) \rho Q$

BEFORE: $V \leftarrow, (((\rho V), K) \rho Q), V$

EXAMPLE: $V \leftarrow 5$
 $K \leftarrow 2$
 $Q \leftarrow 10$

RESULT: AFTER: 1 10 10 2 10 10 3 10 10 4 10 10 5 10 10
BEFORE: 10 10 1 10 10 2 10 10 3 10 10 4 10 10 5

A ALTERNATE IMPLEMENTATIONS:

AFTER: $V \leftarrow (B \leftarrow ((K+1) \times \rho V) \rho (K+1) \uparrow 1) \setminus V$
 $V[(\sim B) / \uparrow \rho V] \leftarrow Q$

BEFORE: $V \leftarrow (B \leftarrow ((K+1) \times \rho V) \rho (-K+1) \uparrow 1) \setminus V$
 $V[(\sim B) / \uparrow \rho V] \leftarrow Q$

A ALTERNATE IMPLEMENTATION, FOR K = 1

AFTER: $V \leftarrow, V, [\Box I O + 0.5] Q$

$\Box I O \leftarrow 1: V \leftarrow, V, [1.5] Q$
 $\Box I O \leftarrow 0: V \leftarrow, V, [0.5] Q$

BEFORE: $V \leftarrow, Q, [\Box I O + 0.5] V$

A NOTE: AXIS-NUMBER DECIMAL-PART IS A DECIMAL VALUE
A BETWEEN 0 AND 1; "0.5" SHOWN HERE

EXAMPLE: INSERTING ASTERISKS

$V \leftarrow 'ABCDEFG'$
 $Q \leftarrow '*'$

RESULT: AFTER: $A * B * C * D * E * F * G *$
BEFORE: $* A * B * C * D * E * F * G$

EXPANDING / INSERTING ELEMENTS INTO A VECTOR V

INSERTING K ELEMENTS Q BEFORE/AFTER THE ELEMENTS WITH INDICES I

TYPE 1: INSERTING PAD-ELEMENTS (0 OR BLANK)

AFTER: $N \leftarrow K \times \rho I \leftarrow, I$ [$Q \leftarrow 0$ OR $Q \leftarrow ' '$]
 $V \leftarrow (V, N\rho Q) [\Delta(I\rho V), N\rho I]$

BEFORE: $N \leftarrow K \times \rho I \leftarrow, I$
 $V \leftarrow ((N\rho Q), V) [\Delta(N\rho I), I\rho V]$

a NOTE: TO INSERT AFTER FIELDS OF WIDTHS "W", SET $I \leftarrow +\backslash W$

EXAMPLE: $V \leftarrow 'NOWISSTHETIME'$
 $I \leftarrow 3 5 8$ [$\square I O \leftarrow 1$]
 $K \leftarrow 2$
 $Q \leftarrow ' '$

RESULT: AFTER: NOW IS THE TIME
BEFORE: NO WI STH ETIME

A ALTERNATE IMPLEMENTATIONS:

AFTER: $I \leftarrow I [\Delta I \leftarrow, I]$
 $B \leftarrow ((K \times N \leftarrow \rho I) + \rho V) \rho 1$
 $B [\cdot, \Delta(K, N) \rho I + \sim \square I O] + \iota K \times N \leftarrow 0$
 $V \leftarrow B \setminus V$

BEFORE: REPLACE " $\sim \square I O$ " WITH " $-\square I O$ "

AFTER: $I \leftarrow I [\Delta I \leftarrow, I]$
 $J \leftarrow (\cdot, \Delta(K, N) \rho I + \sim \square I O) + \iota K \times N \leftarrow \rho I$
 $V \leftarrow (\sim (\iota(K \times N) + \rho V) \in J) \setminus V$

BEFORE: REPLACE " $\sim \square I O$ " WITH " $-\square I O$ "

AFTER: $C \leftarrow ((K+1) \times \rho V) \rho L \leftarrow (K+1) \uparrow 1$
 $V \leftarrow ((\cdot, ((I\rho V) \in I) \circ . \vee L) / C) \setminus V$

BEFORE: REPLACE " $L \leftarrow (K+1) \dots$ " WITH " $L \leftarrow (-K+1) \dots$ "

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EXPANDING / INSERTING ELEMENTS INTO A VECTOR V

INSERTING K ELEMENTS Q BEFORE/AFTER THE ELEMENTS WITH INDICES I (CONTD)

TYPE 1: (CONTD)

a FOR $K = 1$, THESE SIMPLIFY TO:

AFTER: $V \leftarrow (V, (\rho, I)\rho Q)[\Delta(\imath\rho V), (\rho, I)\rho I]$

AFTER: $I \leftarrow I[\Delta I \leftarrow, I]$
 $B \leftarrow ((N \leftarrow \rho I) + \rho V)\rho 1$
 $B[(I + \sim \square IO) + \imath N] \leftarrow 0$
 $V \leftarrow B \setminus V$

AFTER: $I \leftarrow I[\Delta I \leftarrow, I]$
 $V \leftarrow (\sim(N + \rho V) \in (I + \sim \square IO) + \imath N \leftarrow \rho I) \setminus V$

TYPE 2: INSERTING ANY OTHER ELEMENT Q

AFTER: $N \leftarrow K \times \rho I \leftarrow, I$
 $V \leftarrow (V, N\rho Q)[\Delta(\imath\rho V), N\rho I]$

BEFORE: $N \leftarrow K \times \rho I \leftarrow, I$
 $V \leftarrow ((N\rho Q), V)[\Delta(N\rho I), \imath\rho V]$

EXAMPLE: $Q \leftarrow ' * '$
 $K \leftarrow 2$

RESULT: AFTER: NOW**IS**THE**TIME
BEFORE: NO**WI**STH**ETIME

a ALTERNATE IMPLEMENTATION:

AFTER: $I \leftarrow I[\Delta I \leftarrow, I]$
 $B \leftarrow ((K \times N \leftarrow \rho I) + \rho V)\rho 1$
 $B[(\sim Q(K, N)\rho I + \sim \square IO) + \imath K \times N] \leftarrow 0$
 $V \leftarrow B \setminus V$
 $V[(\sim B) / \imath\rho V] \leftarrow Q$

BEFORE: REPLACE " $\sim \square IO$ " WITH " $\sim \square IO$ "

EXPANDING / INSERTING ELEMENTS INTO A VECTOR V

INSERTING ELEMENT Q IN WIDTHS W BEFORE/AFTER THE ELEMENTS WITH INDICES I

TYPE 1: INSERTING PAD-ELEMENTS (0 OR BLANK)

AFTER: $I \leftarrow I[S \leftarrow \Delta I \leftarrow, I]$
 $C \leftarrow (G \times \rho V) \rho (G \leftarrow 1 + [/ W \leftarrow W[S]] \leftarrow 1)$
 $U \leftarrow ((\iota \rho V) \in I) \setminus W$
 $V \leftarrow ((, U \circ . \geq (\iota G) - \square IO) / C) \setminus V$

BEFORE: REPLACE " $(G \leftarrow \dots)$ " WITH " $(-G \leftarrow \dots)$ " AND
" ιG " WITH " $\phi \iota G$ "

- Ⓐ EACH ELEMENT OF W CONTAINS THE NUMBER OF ELEMENTS TO BE INSERTED BEFORE/AFTER THE ELEMENT OF V WHOSE INDEX IS THE CORRESPONDING ELEMENT OF I; $\rho I \leftrightarrow \rho W$

EXAMPLE: $V \leftarrow 7 \ 6 \ 5 \ 4 \ 3 \ 2 \ 1$
 $I \leftarrow 2 \ 5 \ 6 \quad [\square IO \leftarrow 1]$
 $W \leftarrow 1 \ 3 \ 2$

RESULT: AFTER: 7 6 0 5 4 3 0 0 0 2 0 0 1

- Ⓐ ALTERNATE IMPLEMENTATIONS:

AFTER: $I \leftarrow I[S \leftarrow \Delta I \leftarrow, I]$
 $K \leftarrow \square IO ++ / (\iota \rho V) \circ . > I$
 $J \leftarrow (\iota \rho V) + (+ \setminus 0, W \leftarrow W[S]) [K]$
 $V \leftarrow ((\iota (+ / W) + \rho V) \in J) \setminus V \quad **$

BEFORE: REPLACE " $\circ . >$ " WITH " $\circ . \geq$ "

** ADAPTED FROM (1) THE APL IDIOM LIST

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EXPANDING / INSERTING ELEMENTS INTO A VECTOR V

INSERTING ELEMENT Q IN WIDTHS W BEFORE/AFTER THE ELEMENTS WITH INDICES I (CONTD)

TYPE 2: INSERTING ANY OTHER ELEMENT Q

AFTER: $I \leftarrow I[S \leftarrow \Delta I \leftarrow, I]$
 $C \leftarrow (G \times \rho V) \rho (G \leftarrow 1 + [/W \leftarrow W[S]] \leftarrow 1$
 $U \leftarrow ((\iota \rho V) \in I) \setminus W$
 $V \leftarrow (B \leftarrow (, U \circ . \geq (\iota G) - \square IO) / C) \setminus V$
 $V[(\sim B) / \iota \rho V] \leftarrow Q$

BEFORE: REPLACE " $(G \leftarrow \dots)$ " WITH " $(-G \leftarrow \dots)$ " AND
" ιG " WITH " $\phi \iota G$ "

EXAMPLE: $Q \leftarrow -1$

RESULT: 7 6 -1 5 4 3 -1 -1 -1 2 -1 -1 1

EXPANDING / INSERTING ELEMENTS INTO A VECTOR V

EXPANDING FIELDS WITH DIFFERENT WIDTHS W TO FIELDS OF THE SAME WIDTH L

RIGHT-JUSTIFIED FIELDS

$V \leftarrow (, W \circ . > \phi(1L) - \square I O) \setminus V$

- Ⓐ INSERTS PAD-ELEMENTS (0 OR BLANK)
- Ⓐ "L" MUST BE $\geq \lceil W \rceil$

EXAMPLE: $V \leftarrow 'AABCDABABC'$
 $W \leftarrow 1 \ 4 \ 2 \ 3$
 $L \leftarrow 4$

RESULT: $AABCD \ AB \ ABC$

- Ⓐ ALTERNATE IMPLEMENTATIONS:

$V \leftarrow (, (W - \sim \square I O) \circ . \geq \phi(1L)) \setminus V$

$V \leftarrow (, (L - W) \circ . \leq (1L) - \square I O) \setminus V$

LEFT-JUSTIFIED FIELDS

$V \leftarrow (, W \circ . > (1L) - \square I O) \setminus V$

RESULT: $A \ ABCDAB \ ABC$

- Ⓐ ALTERNATE IMPLEMENTATIONS:

$V \leftarrow (, W \circ . \geq (1L) + \sim \square I O) \setminus V$

$V \leftarrow (, (W - \sim \square I O) \circ . \geq 1L) \setminus V$

- Ⓐ NOTE: THESE ARE "KERNEL" APL OPERATIONS

EXPANDING / INSERTING ELEMENTS INTO A VECTOR V

INSERTING ELEMENT Q AFTER EVERY "K"TH ELEMENT OF V

$V \leftarrow (((\lceil (\rho V) \div K \rceil), K) \rho V), Q$

• Q IS A SCALAR; Q MAY BE A VECTOR ONLY IF $\rho Q \leftrightarrow \lceil (\rho V) \div K \rceil$

EXAMPLE: $V \leftarrow '123178'$
 $K \leftarrow 2$
 $Q \leftarrow '/'$

RESULT: 12/31/78/

• NOTE: MAY ALSO CATENATE Q AT THE LEFT, BEFORE THE RAVEL.

• LEADING Q MAY BE DELETED VIA: $V \leftarrow 1 \downarrow, \dots$
• THEN THE EXAMPLE CAN BE SIMPLIFIED TO:

$V \leftarrow 1 \downarrow, '/', 3 2 \rho V$

• NOTE: MAY NEED TO DELETE TRAILING OCCURRENCES OF Q AND/OR EXTRANEOUS ELEMENTS OF V PRODUCED BY THE RESHAPE:

$V \leftarrow (-1 + R + \rho V) \rho (((R \leftarrow \lceil (\rho V) \div K \rceil), K) \rho V), Q$

RESULT: 12/31/78

EXPANDING / INSERTING ELEMENTS INTO A VECTOR V

INSERTING A STRING S AFTER THE ELEMENT WITH INDEX I

$V \leftarrow ((I + \sim \square I O) \downarrow V), S, (I + \sim \square I O) \downarrow V$

$\square I O \leftarrow 1 : V \leftarrow (I \uparrow V), S, I \downarrow V$

$\square I O \leftarrow 0 : V \leftarrow ((I + 1) \uparrow V), S, (I + 1) \downarrow V$

• S MAY BE A SCALAR OR VECTOR

EXAMPLE: $V \leftarrow 'ABCDHIJ'$

$S \leftarrow 'EFG'$

$I \leftarrow 4 \quad [\square I O \leftarrow 1]$

RESULT: ABCDEFGHIJ

• ALTERNATE IMPLEMENTATION:

$V \leftarrow (V, S)[\Delta(\iota \rho V), (\rho S) \rho I] \quad **$

• TO INSERT S AFTER SEVERAL ELEMENTS:

$N \leftarrow (\rho S \leftarrow, S) \times \rho I \leftarrow, I$

$V \leftarrow (V, N \rho S)[\Delta(\iota \rho V), , \Delta((\rho S), \rho I) \rho I]$

EXAMPLE: $V \leftarrow 'B \leftarrow (B = 0) + B \div 15'$

$S \leftarrow '[3]'$

$I \leftarrow 3 \ 8 \ 0 \quad [\square I O \leftarrow 0]$

RESULT: B[3] $\leftarrow (B[3] = 0) + B[3] \div 15$

• NOTE: SEE ALSO THE TECHNIQUE "REPLACING MULTIPLE OCCURRENCES ..."

** ADAPTED FROM (1) THE APL IDIOM LIST

EXPANDING / INSERTING ELEMENTS INTO A VECTOR V

EXPANDING V TO LENGTH L

PADDING WITH THE PAD-ELEMENT (0 OR BLANK)

$V \leftarrow L \uparrow V$

EXAMPLE: $V \leftarrow 17$
 $L \leftarrow 15$

RESULT: 1 2 3 4 5 6 7 0 0 0 0 0 0 0 0

A ALTERNATE IMPLEMENTATION:

$V \leftarrow L \uparrow V, L \rho Q$ $[Q \leftarrow 0 \text{ OR } Q \leftarrow ' ']$

PADDING WITH THE LAST ELEMENT

$V \leftarrow L \uparrow V, L \rho^{-1} \uparrow V$

RESULT: 1 2 3 4 5 6 7 7 7 7 7 7 7 7 7

A ALTERNATE IMPLEMENTATION:

$V \leftarrow V [(1L) \lfloor (\rho V) - \sim \square I O]$

TESTING THE ELEMENTS IN A VECTOR V

DETERMINING IF ELEMENT Q OCCURS IN V

$R \leftarrow Q \in V$

• RESULT R IS 1 IF Q OCCURS IN V AND 0 IF IT DOESN'T

• IF Q IS A VECTOR, R IS A VECTOR OF THE SAME LENGTH

EXAMPLE: $V \leftarrow 'WE\ THE\ PEOPLE'$
 $Q \leftarrow 'LATE'$

RESULT: 1 0 1 1

• ALTERNATE IMPLEMENTATIONS, WHEN Q IS A SCALAR:

$R \leftarrow V / V = Q$ OR $R \leftarrow V V . = Q$

$R \leftarrow 0 < + / V = Q$ OR $R \leftarrow 0 < V + . = Q$

• ALTERNATE IMPLEMENTATIONS, WHEN Q IS EITHER VECTOR
• OR SCALAR:

$R \leftarrow (\Box I O + \rho V) > V \downarrow Q$

$\Box I O \leftarrow 1: R \leftarrow (1 + \rho V) > V \downarrow Q$
 $\Box I O \leftarrow 0: R \leftarrow (\rho V) > V \downarrow Q$

$R \leftarrow V / Q \circ . = V$

$R \leftarrow ((\rho V) - \sim \Box I O) \geq V \downarrow Q$

$\Box I O \leftarrow 1: R \leftarrow (\rho V) \geq V \downarrow Q$
 $\Box I O \leftarrow 0: R \leftarrow ((\rho V) - 1) \geq V \downarrow Q$

TESTING THE ELEMENTS IN A VECTOR V

DETERMINING IN WHICH FIELD OF V AN ELEMENT Q OCCURS

- Ⓐ FIND THE INDICES OF THE OCCURRENCES OF THE ELEMENT Q
- Ⓐ IN V; RANGE-CHECK THESE INDICES AGAINST THE INDICES
- Ⓐ OF THE FIELD BOUNDARIES

$OC \leftrightarrow / (I \leftarrow (V = Q) / \text{ip} V) . \geq FB$

- Ⓐ "FB" IS AN $N \times 2$ MATRIX WHERE EACH ROW CONTAINS THE LOWER AND UPPER BOUNDARY INDICES OF A FIELD (SEE TECHNIQUE "FINDING THE BOUNDARY INDICES ..."). THE INDICES USED FOR THESE BOUNDS ARE DEPENDENT ON THE RELATIONAL FUNCTION USED ($>$ OR \geq).

- Ⓐ NOTE: " $\neq / N \circ. \geq R$ " IS A "KERNEL" APL OPERATION FOR RANGE-CHECKING THE NUMBERS N AGAINST THE LOWER AND UPPER RANGE LIMITS R

EXAMPLE: $V \leftarrow '55.55\ 59.55\ 59.59\ 50.50\ 50.59\ 90.09'$
 $FB \leftarrow 6\ 2\ \text{p} 1\ 6\ 7\ 12\ 13\ 18\ 19\ 24\ 25\ 30\ 31\ 36\ [\square I O \leftarrow 1]$
 $Q \leftarrow '9'$

RESULT: BOUNDS: $6\ 12\ 18\ 24\ 30\ 36$
 $1\ 7\ 13\ 19\ 25\ 31$

<u>INDICES:</u>	8	0	1	0	0	0	0
	14	0	0	1	0	0	0
	17	0	0	1	0	0	0
	29	0	0	0	0	1	0
	31	0	0	0	0	0	1
	35	0	0	0	0	0	1

- Ⓐ THE RESULTANT BIT MATRIX "OC" HAS 1 ROW FOR EACH INDEX OCCURRENCE OF Q, AND 1 COLUMN FOR EACH FIELD DEFINED IN "FB", I.E., $\rho OC \leftrightarrow (\rho I), 1 \uparrow \rho FB$. A 0 OR 1 INDICATES THE ABSENCE OR PRESENCE OF THAT OCCURRENCE OF Q IN THE FIELD
- Ⓐ EACH COLUMN OF "OC" CAN BE USED TO SELECT THE INDICES THAT OCCUR IN FIELD "K", I.E.: $OC[; K] / I$

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TESTING THE ELEMENTS IN A VECTOR V

DETERMINING IN WHICH FIELD OF V AN ELEMENT Q OCCURS (CONTD)

- Ⓐ THE FIRST OCCURRENCE OF Q IN FIELD "K" CAN BE DETERMINED
 - Ⓐ USING: $T \leftarrow <\setminus OC$
 - Ⓐ AND THEN: $T[;K]/I$
- Ⓐ $V \neq OC$ INDICATES WHICH FIELDS CONTAIN Q
- Ⓐ THE COLUMNS CAN BE SUMMED TO COUNT THE NUMBER OF OCCURRENCES OF Q IN THE FIELDS, I.E.: $+ \neq OC$

- Ⓐ TO TEST FOR ANY OF SEVERAL DIFFERENT ELEMENTS "DQ",
 - Ⓐ REPLACE " $V = Q$ " WITH " $V \in DQ$ " OR " $V/V \circ . = DQ$ "
- Ⓐ THEN V/OC INDICATES WHICH ELEMENTS OF "DQ" OCCUR IN SOME FIELD

TESTING THE ELEMENTS IN A VECTOR V

COUNTING THE NUMBER OF OCCURRENCES N OF ELEMENTS Q IN V

$N \leftarrow + / Q \circ . = V$

a "N" CONTAINS THE COUNTS FOR EACH RESPECTIVE ELEMENT IN Q

a IF Q IS A SINGLE ELEMENT, THIS SIMPLIFIES TO:

$N \leftarrow + / Q = V$ OR $N \leftarrow Q + . = V$

EXAMPLE: $V \leftarrow 'ALPHA, BETA, GAMMA, DELTA, EPSILON'$
 $Q \leftarrow ', AFIT'$

RESULT: 4 6 0 1 2

a TO COUNT THE GRAND TOTAL OF ALL OCCURRENCES OF ELEMENTS Q
a IN V:

$N \leftarrow + / V \in Q$

RESULT: 13

TESTING THE ELEMENTS IN A VECTOR V

PERFORMING RELATIONAL TESTS ALONG V

$R \leftarrow (\neg 1 \downarrow V) \alpha 1 \downarrow V$

- Ⓐ THIS REPRESENTS: $(V[1] \alpha V[2]), (V[2] \alpha V[3]), \dots,$
 $V[\neg 1 \downarrow V] \alpha V[\rho V]$ $[\square I O \leftarrow 1]$
- Ⓐ " α " IS ONE OF THE RELATIONAL FUNCTIONS $< \leq = \neq \geq >$
- Ⓐ FOR NUMBERS AND $= \neq$ FOR CHARACTERS
- Ⓐ TO TEST IF THE RELATION HOLDS ALONG V, SUBSTITUTE
 $R \leftarrow \wedge / \dots$ OR $\dots \wedge . \alpha \dots$
- Ⓐ $\rho R \leftrightarrow (\rho V) - 1$
- Ⓐ REDUCTION (α / V) DOES NOT PRODUCE THIS RESULT, SINCE ITS
INTERMEDIATE RIGHT-COMPARANDS BECOME BOOLEAN AFTER THE
RIGHTMOST COMPARISON

EXAMPLE: TESTING FOR " $<$ " ALONG V

$V \leftarrow 1 2 4 6 5 9 13 17$

RESULT: 1 1 1 0 1 1 1

- Ⓐ ALTERNATE IMPLEMENTATIONS $[\rho R \leftrightarrow \rho V]:$

Ⓐ FOR \leq : $R \leftarrow (\Delta V) = 1 \rho V$ **

Ⓐ FOR ALL $=$: $R \leftarrow \wedge / V = 1 \rho V$ OR $R \leftarrow V \wedge . = 1 \rho V$ **

** ADAPTED FROM (1) THE APL IDIOM LIST

TESTING THE ELEMENTS IN A VECTOR V

DETERMINING IF ALL THE ELEMENTS OF V ARE UNIQUE

$$R \leftarrow \wedge / (\sqcup \rho V) = V \sqcup V \quad **$$

EXAMPLE: $V \leftarrow \text{t c o n u i t} | \alpha \Gamma \sqcup \nabla \Delta \circ \square * \circ \sqcup \downarrow \sqcap \sim \rho \in \omega \alpha ? < \leq = \geq > \neq \vee \wedge ^t$

RESULT: 0

A ALTERNATE IMPLEMENTATION:

$$R \leftarrow \sim 0 \in (\sqcup \rho V) = V \sqcup V$$

** ADAPTED FROM (1) THE APL IDIOM LIST

SELECTING ELEMENTS OF A VECTOR V

SELECTING ELEMENTS THAT SATISFY A TEST

`R←(TEST)/V`

- Ⓐ THE "TEST" MUST PRODUCE A BOOLEAN RESULT (E.G., USING
- Ⓐ A LOGICAL OR RELATIONAL EXPRESSION) WHICH IS A SCALAR
- Ⓐ OR A VECTOR WITH THE SAME LENGTH AS V
- Ⓐ IF NO ELEMENTS ARE SELECTED, THE RESULT IS AN EMPTY VECTOR

EXAMPLE: *SELECTING ELEMENTS > 5*

`R←(V>5)/V←2 5 8 13 19`

RESULT: 8 13 19

EXAMPLE: *SELECTING ELEMENTS ≠ BLANKS*

`R←(V≠' ') / V←' THIS IS A CHAR. LINE'`

RESULT: THISISACHAR.LINE

EXAMPLE: *SELECTING / DELETING A SUBSTRING*

`R←'**DATE',((TEST)/-RANGE'), ' ERROR'
TEST←0`

RESULT: **DATE ERROR

- Ⓐ NOTE: THE CODE FOR OTHER "TESTS" MAY BE EXTRACTED FROM
- Ⓐ THE APPROPRIATE TECHNIQUES IN THIS GUIDE. FOR
- Ⓐ EXAMPLE, THE TEST FOR "ALL LEADING OCCURRENCES" MAY BE
- Ⓐ FOUND IN THE TECHNIQUE FOR DELETING SUCH OCCURRENCES.
- Ⓐ ADDITIONAL TESTS ARE SHOWN ON THE FOLLOWING PAGES.

SELECTING ELEMENTS OF A VECTOR V

SELECTING ELEMENTS P WHICH ARE BETWEEN PAIRED DELIMITERS D

TYPE 1: ONLY 1 TYPE OF DELIMITER ELEMENT

$P \leftarrow (B \geq 1 \downarrow \neq \backslash 1, B \leftarrow D = V) / V$

a THE RESULT WILL INCLUDE THE DELIMITERS AND THE ELEMENTS
a BETWEEN THEM

a CAUTION: NO "NESTING" OF PAIRED DELIMITERS IS ALLOWED

EXAMPLE: BETWEEN PAIRED QUOTATION MARKS ("")

$V \leftarrow \text{'THE "BEST" ANSWER IS "LIMIT".}'$
 $D \leftarrow \text{''}'$

RESULT: "BEST""LIMIT"

a ALTERNATE IMPLEMENTATION:

$P \leftarrow (C \leq 1 \downarrow = \backslash 0, C \leftarrow D \neq V) / V$

a TO SELECT WITHOUT THE DELIMITERS:

$P \leftarrow (B \neq 1 \downarrow \neq \backslash 1, B \leftarrow D = V) / V$

$P \leftarrow (C \wedge 1 \downarrow = \backslash 0, C \leftarrow D \neq V) / V$

RESULT: BESTLIMIT

a NOTE: THE TEST FOR BALANCED DELIMITERS IS:

$O = 2 \mid + / B \quad OR \quad O = 2 \mid + / D = V$

(CONT'D ON NEXT PAGE)

SELECTING ELEMENTS OF A VECTOR V

SELECTING ELEMENTS P WHICH ARE BETWEEN PAIRED DELIMITERS D
(CONTD)

TYPE 2: LEFT AND RIGHT DELIMITER ELEMENTS

$P \leftarrow (L \leq + \setminus (V = 1 \uparrow D) -^{\sim} 1 \downarrow 0, V = 1 \downarrow D) / V$

- Ⓐ "D" CONTAINS THE DELIMITERS IN THE ORDER OF PAIRING,
- Ⓐ E.G., $D \leftarrow '[]'$
- Ⓐ THE RESULT WILL INCLUDE THE DELIMITERS AND THE ELEMENTS
- Ⓐ BETWEEN THEM
- Ⓐ "L" IS THE LEVEL OF NESTING OF THE PAIRED DELIMITERS
- Ⓐ TO BE SELECTED

EXAMPLE: BETWEEN PARENTHESES

$V \leftarrow '((\wp R) = R \wp R) / R \leftarrow (5 | N) * 2'$
 $D \leftarrow '()''$
 $L \leftarrow 1$

RESULT: $((\wp R) = R \wp R)(5 | N)$

ALTERNATE IMPLEMENTATION:

$P \leftarrow (L \leq + \setminus 1 \downarrow - \neq 0 \sim 1 \phi 0, D \circ . = V) / V$

- Ⓐ TO SELECT WITHOUT THE DELIMITERS FOR LEVEL "L":

$P \leftarrow (L \leq + \setminus (\sim 1 \downarrow 0, V = 1 \uparrow D) - V = 1 \downarrow D) / V$

$P \leftarrow (L \leq + \setminus 1 \downarrow - \neq \sim 1 \phi 0, D \circ . = V) / V$

RESULT: $(\wp R) = R \wp R 5 | N$

- Ⓐ NOTE: TESTS FOR BALANCED DELIMITERS ARE:

$\wedge / 0 \leq + \setminus (V = 1 \uparrow D) - V = 1 \downarrow D$ OR $\wedge / 0 \leq + \setminus - \neq D \circ . = V$

SELECTING ELEMENTS OF A VECTOR V

SELECTING ELEMENTS P WHICH ARE OUTSIDE PAIRED DELIMITERS D

TYPE 1: ONLY 1 TYPE OF DELIMITER ELEMENT

$P \leftarrow (B \vee 1 \downarrow \neq \backslash 1, B \leftarrow D = V) / V$

- THE RESULT WILL INCLUDE THE DELIMITERS AND THE ELEMENTS
- OUTSIDE THEM

- CAUTION: NO "NESTING" OF PAIRED DELIMITERS IS ALLOWED

EXAMPLE: OUTSIDE PAIRED QUOTATION MARKS ("")

$V \leftarrow "THE "BEST" ANSWER IS "LIMIT"."$
 $D \leftarrow "$

RESULT: THE "" ANSWER IS "".

- ALTERNATE IMPLEMENTATION:

$P \leftarrow (C \wedge 1 \downarrow \neq \backslash 0, C \leftarrow D \neq V) / V$

- TO SELECT WITHOUT THE DELIMITERS:

$P \leftarrow (B < 1 \downarrow \neq \backslash 1, B \leftarrow D = V) / V$

$P \leftarrow (C > 1 \downarrow \neq \backslash 0, C \leftarrow D \neq V) / V$

RESULT: THE ANSWER IS .

(CONT'D ON NEXT PAGE)

SELECTING ELEMENTS OF A VECTOR V

SELECTING ELEMENTS P WHICH ARE OUTSIDE PAIRED DELIMITERS D (CONTD)

TYPE 2: LEFT AND RIGHT DELIMITER ELEMENTS

$P \leftarrow (L >+ \backslash (-1 \downarrow 0, V = 1 \uparrow D) - V = 1 \downarrow D) / V$

- Ⓐ "D" CONTAINS THE DELIMITERS IN THE ORDER OF PAIRING,
E.G., $D \leftarrow '[]'$
- Ⓐ THE RESULT WILL INCLUDE THE DELIMITERS AND THE ELEMENTS
OUTSIDE THEM
- Ⓐ "L" IS THE LEVEL OF NESTING OF THE PAIRED DELIMITERS
- Ⓐ TO BE SELECTED

EXAMPLE: OUTSIDE PARENTHESES

$V \leftarrow '((1 \rho R) = R 1 R) / R \leftarrow (5 | N) * 2'$
 $D \leftarrow '()''$
 $L \leftarrow 1$

RESULT: $() / R \leftarrow () * 2$

ALTERNATE IMPLEMENTATION:

$P \leftarrow (L >+ \backslash 1 \downarrow - \not= -1 0 \phi 0, D \circ . = V) / V$

TO SELECT WITHOUT THE DELIMITERS FOR LEVEL "L":

$P \leftarrow (L >+ \backslash (V = 1 \uparrow D) - -1 \downarrow 0, V = 1 \downarrow D) / V$

$P \leftarrow (L >+ \backslash 1 \downarrow - \not= 0 -1 \phi 0, D \circ . = V) / V$

RESULT: $/ R \leftarrow * 2$

SELECTING ELEMENTS OF A VECTOR V

SELECTING SUBSTRING S WITH STARTING INDEX I AND LENGTH L

$S \leftarrow L \uparrow (I - \square I O) \downarrow V$

EXAMPLE: $V \leftarrow 'THESE ARE THE TIMES'$
 $I \leftarrow 6$ $[\square I O \leftarrow 1]$
 $L \leftarrow 8$

RESULT: ARE THE

a ALTERNATE IMPLEMENTATION:

$S \leftarrow V[(I - \square I O) + 1 L]$

a TO SELECT MULTIPLE SUBSTRINGS WITH SAME LENGTH:

$S \leftarrow V[, (I - \square I O) \circ . + 1 L]$

EXAMPLE: $I \leftarrow 8 1 17$ $[\square I O \leftarrow 1]$
 $L \leftarrow 3$

RESULT: RE THEMES

SELECTING ELEMENTS OF A VECTOR V

SELECTING LEFT AND RIGHT FIELDS OF V DELIMITED BY THE ELEMENT Q

$R \leftarrow (1 + \rho L \leftarrow ((V \downarrow Q) - \square IO) \uparrow V) + V$

EXAMPLE: $V \leftarrow 'PARM1,ARG2'$
 $Q \leftarrow ',','$

RESULT: $L: PARM1$
 $R: ARG2$

SELECTING ELEMENTS OF A VECTOR V

SELECTING FIELD N OF V

TYPE 1: USING A FIELD PARTITION VECTOR P

- Ⓐ MUST FIRST GENERATE A LOGICAL VECTOR P DEFINING THE FIELD PARTITION OF V, WITH A 1-BIT FOR THE 1ST ELEMENT OF EACH FIELD OF V AND 0'S OTHERWISE (SEE SECTION "GENERATING A LOGICAL VECTOR").
- Ⓐ ALSO $\rho P \leftrightarrow \rho V$
- Ⓐ CAUTION: ANY FIELD DELIMITERS MUST BE DELETED FROM V

$F \leftarrow (N = +\setminus P) / V$

- Ⓐ "N" IS THE NUMBER OF THE FIELD
- Ⓐ NOTE: "+\P" IS A "KERNEL" APL OPERATION

EXAMPLE: $V \leftarrow '111112223344455666667'$
 $P \leftarrow 1 0 0 0 0 1 0 0 1 0 1 0 0 1 0 1 0 0 0 0 1$
 $N \leftarrow 6$

RESULT: 666666

- Ⓐ ALTERNATE IMPLEMENTATIONS, WHEN N IS A VECTOR:

$F \leftarrow ((+\setminus P) \in N) / V$

$F \leftarrow (V \neq N \circ . = +\setminus P) / V$

EXAMPLE: $N \leftarrow 2 5 7$

RESULT: 222557

(CONT'D ON NEXT PAGE)

SELECTING ELEMENTS OF A VECTOR V

SELECTING FIELD N OF V (CONTD)

TYPE 2: USING THE INDEX OF THE FIRST ELEMENT AND THE FIELD WIDTH

Ⓐ PERFORM THE FOLLOWING 3 TECHNIQUES:

- Ⓐ 1. COMPUTE WIDTHS W OF THE FIELDS OF V
- Ⓐ 2. FIND THE STARTING (BOUNDARY) INDICES I OF EACH FIELD
- Ⓐ 3. USE THESE TO SELECT THE SUBSTRING "FIELD N" VIA:

$F \leftarrow W[N] \uparrow (I[N] - \square IO) \downarrow V$

Ⓐ "N" IS THE INDEX-NUMBER OF THE FIELD

FINDING INDICES OF ELEMENTS OF A VECTOR V

FINDING THE INDICES OF ELEMENTS THAT SATISFY A TEST

$I \leftarrow (\text{TEST}) / \text{vp} V$

A NOTE: THIS IS A "KERNEL" APL OPERATION

EXAMPLE: FINDING THE INDICES OF THE DELIMITER "n"

$V \leftarrow 'nALPHA nBETA nGAMMA nPi nZETA'$
 $I \leftarrow (V = 'n') / \text{vp} V$

RESULT: 1 7 12 18 21 [$\square I O \leftarrow 1$]

A NOTE: TO OBTAIN THE INDICES FOR A SPECIFIC
INDEX ORIGIN, ADD:

$\square I O \leftarrow 1: I \leftarrow (\sim \square I O) + (\text{TEST}) / \text{vp} V$

$\square I O \leftarrow 0: I \leftarrow (-\square I O) + (\text{TEST}) / \text{vp} V$

FINDING INDICES OF ELEMENTS OF A VECTOR V

FINDING THE INDEX OF THE 1ST OCCURRENCE OF ELEMENTS Q

$I \leftarrow V \sqcap Q$

EXAMPLE: $V \leftarrow 'EDCBAJIHGFEJDIZG'$
 $Q \leftarrow 'GADH'$

RESULT: 9 5 2 8 $[\Box I O \leftarrow 1]$

a ALTERNATE IMPLEMENTATION:

$I \leftarrow \Box I O ++ / \wedge \backslash Q \circ . \neq V$

a ALTERNATE IMPLEMENTATIONS, WHEN Q IS A SCALAR OR
a 1-ELEMENT VECTOR:

$I \leftarrow 1 \uparrow (V = Q) / \sqcap \rho V$

$I \leftarrow (< \backslash V = Q) / \sqcap \rho V$

FINDING INDICES OF ELEMENTS OF A VECTOR V

FINDING THE INDEX OF THE LAST OCCURRENCE OF ELEMENTS Q

$I \leftarrow (-1 \ 1[2 \times \square I O] + \rho V) - (\phi V) \downarrow Q$

$\square I O \leftarrow 1 : \quad I \leftarrow (1 + \rho V) - (\phi V) \downarrow Q$
 $\square I O \leftarrow 0 : \quad I \leftarrow (-1 + \rho V) - (\phi V) \downarrow Q$

EXAMPLE: $V \leftarrow 'EDCBAJIHGFEDIZG'$
 $Q \leftarrow 'GADHX'$

RESULT: 16 5 13 8 0 $[\square I O \leftarrow 1]$

A ALTERNATE IMPLEMENTATIONS:

$I \leftarrow (((2 \times \square I O) - 1) + \rho V) - (\phi V) \downarrow Q$

$I \leftarrow ((-1 * \sim \square I O) + \rho V) - (\phi V) \downarrow Q$

$I \leftarrow (+/\vee \setminus Q \circ . = \phi V) - \sim \square I O$

A ALTERNATE IMPLEMENTATION, WHEN Q IS A SCALAR OR
A 1-ELEMENT VECTOR:

$I \leftarrow -1 \uparrow (V = Q) / \downarrow \rho V$

FINDING INDICES OF ELEMENTS OF A VECTOR V

FINDING THE INDICES I OF THE SMALLEST AND LARGEST ELEMENTS

a THE SMALLEST ELEMENT:

$I \leftarrow V \downarrow 1 / V$ **

a NOTE: FINDS INDEX OF THE 1ST OCCURRENCE

EXAMPLE: $V \leftarrow 14 \ 76 \ 46 \ 54 \ 22 \ 5 \ 68 \ 68 \ 94 \ 39$

RESULT: 6 [□IO←1]

a ALTERNATE IMPLEMENTATIONS:

$I \leftarrow 1 \uparrow \Delta V$ OR $I \leftarrow -1 \uparrow \Psi V$

a NOTE: "... -1↑..." FINDS THE LAST OCCURRENCE

a THE LARGEST ELEMENT:

$I \leftarrow V \uparrow 1 / V$ **

RESULT: 9 [□IO←1]

a ALTERNATE IMPLEMENTATIONS:

$I \leftarrow 1 \uparrow \Psi V$ OR $I \leftarrow -1 \uparrow \Delta V$

** ADAPTED FROM (1) THE APL IDIOM LIST

FINDING INDICES OF ELEMENTS OF A VECTOR V

FINDING THE STARTING INDICES I OF OCCURRENCES OF A PATTERN OF ELEMENTS

FINDING ALL OCCURRENCES OF A SUBSTRING S

- Ⓐ FIND INDICES OF ALL OCCURRENCES OF 1ST ELEMENT OF SUBSTRING, EXCEPT ANY THAT ARE TOO CLOSE TO END OF V

$I \leftarrow (L \downarrow V = 1 \uparrow S) / \iota(\rho V) + L \leftarrow 1 - \rho S \leftarrow, S$

- Ⓐ EXTRACT THE SUBSTRINGS AND KEEP ONLY THE INDICES OF THE IDENTICAL ONES

$I \leftarrow (V[(I - \Box IO) \circ . + \iota \rho S] \wedge . = S) / I$

- Ⓐ NOTE: IF " ρI " WILL BE GREATER THAN " ρS ", CODE
- Ⓐ ... $V[I \circ . + (\iota \rho S) - \Box IO]...$

EXAMPLE: $V \leftarrow 'STORE THE FIRST INSTANCE OF "ST" LAST'$
 $S \leftarrow 'ST'$

RESULT: 1 14 19 30 36 $[\Box IO \leftarrow 1]$

- Ⓐ RESULT IS THE EMPTY VECTOR WHEN THE SUBSTRING IS NOT FOUND

- Ⓐ ALTERNATE IMPLEMENTATIONS:

$I \leftarrow ((-L) \downarrow S \wedge . = (L, 1 + \rho V) \rho V) / \iota(\rho V) + 1 - L \leftarrow \rho S \leftarrow, S$ **

$I \leftarrow (\wedge f((\iota \rho S) - \Box IO) \phi(S \leftarrow, S) \circ . = V) / \iota \rho V$

- Ⓐ NOTE: THIS LAST IMPLEMENTATION FINDS OCCURRENCES WRAPPED AROUND THE ENDS OF V. TO AVOID THIS:

$I \leftarrow (1 + \wedge f((\iota \rho S) - \Box IO) \phi 0, (S \leftarrow, S) \circ . = V) / \iota \rho V$

** ADAPTED FROM (3) USE AND MISUSE OF APL

FINDING INDICES OF ELEMENTS OF A VECTOR V

FINDING THE STARTING INDICES I OF OCCURRENCES OF A PATTERN OF ELEMENTS

FINDING ALL OCCURRENCES OF A WORD S

A NOTE: IGNORES ANY OCCURRENCE OF THE WORD THAT IS
A EMBEDDED WITHIN ANOTHER WORD

A FIND INDICES OF ALL OCCURRENCES OF 1ST ELEMENT OF
A WORD, EXCEPT ANY THAT ARE TOO CLOSE TO END OF V

$I \leftarrow (L \downarrow V = 1 \uparrow S) / i(\rho V) + L \leftarrow 1 - \rho S \leftarrow, S$

A EXTRACT THE SUBSTRINGS AND KEEP ONLY THE INDICES
A OF THE IDENTICAL ONES

$I \leftarrow (V[(I - \square I O) \circ . + i \rho S] \wedge . = S) / I$

A COMPUTE THE INDICES OF THE ELEMENTS IMMEDIATELY
A BEFORE AND AFTER EACH SUBSTRING, AND RANGE-CHECK

$L \leftarrow, \neq / (J \leftarrow I \circ . + ^{-} 1, \rho S) \circ . > (0, \rho V) - \sim \square I O$

A KEEP ONLY THE STARTING INDICES OF THE SUBSTRINGS
A WHOSE ADJACENT ELEMENTS ARE NON-WORD ELEMENTS OR
A AT THE VECTOR ENDS

A NOTE: "ALF" IS A VECTOR OF VALID ELEMENTS FOR
A WORDS OR LABELS

$I \leftarrow (\sim v / (\rho J) \rho L \setminus V[L, J] \in ALF) / I$

EXAMPLE: $V \leftarrow$ 'STORE THE FIRST INSTANCE OF "ST" LAST'
 $S \leftarrow$ 'ST'
 $ALF \leftarrow$ 'ABCDEF~~GHIJKLMNO~~PQRSTUVWXYZΔ0123456789'
 $ALF \leftarrow ALF, 'ABCDEF~~GHIJKLMNO~~PQRSTUVWXYZΔ'$

RESULT: 30 $[\square I O \leftarrow 1]$

FINDING INDICES OF ELEMENTS OF A VECTOR V

FINDING THE BOUNDARY INDICES OF THE FIELDS OF V

WHEN THERE ARE NO FIELD DELIMITERS

TYPE 1: FROM A VECTOR OF FIELD-WIDTHS W, WHERE $\rho V \leftrightarrow +/W$

FIRST ELEMENTS: $LB \leftarrow +\backslash^{-1} \square IO, W$

LAST ELEMENTS: $UB \leftarrow (+\backslash W) - \sim \square IO$

EXAMPLE: $W \leftarrow 5 \ 2 \ 3 \ 1 \ 4$

RESULT: $LB: \begin{matrix} 1 & 6 & 8 & 11 & 12 \end{matrix} \quad [\square IO \leftarrow 1]$
 $UB: \begin{matrix} 5 & 7 & 10 & 11 & 15 \end{matrix}$

$LB: \begin{matrix} 0 & 5 & 7 & 10 & 11 \end{matrix} \quad [\square IO \leftarrow 0]$
 $UB: \begin{matrix} 4 & 6 & 9 & 10 & 14 \end{matrix}$

A NOTE: FOR "K" FIELDS WITH SAME WIDTH "L", SET " $W \leftarrow K \rho L$ "

A NOTE: TO OBTAIN THE INDICES FOR A SPECIFIC
INDEX ORIGIN, ADD:

$\square IO \leftarrow 1: LB \leftarrow (\sim \square IO) + \dots$

$\square IO \leftarrow 0: LB \leftarrow (-\square IO) + \dots$

A [LIKEWISE FOR "UB"]

FINDING INDICES OF ELEMENTS OF A VECTOR V

FINDING THE BOUNDARY INDICES OF THE FIELDS OF V (CONTD)

WHEN THERE ARE NO FIELD DELIMITERS (CONTD)

TYPE 2: WHEN V CONTAINS FIELDS OF IDENTICAL ELEMENTS

FIRST ELEMENTS: $LB \leftarrow (1, (1+V) \neq -1+V) / \text{ip}V$

LAST ELEMENTS: $UB \leftarrow ((1+V) \neq -1+V, 1) / \text{ip}V$

- Ⓐ NOTE: IF " $\text{ip}V$ " IS REPLACED BY "V", THE BOUNDARY
- Ⓐ ELEMENTS (FIRST OR LAST) OF EACH FIELD WILL BE
- Ⓐ SELECTED

EXAMPLE: $V \leftarrow 'AABBBBCDDDEEEE'$

RESULT: $LB: 1 \ 3 \ 7 \ 8 \ 11 \quad [\Box IO \leftarrow 1]$
 $UB: 2 \ 6 \ 7 \ 10 \ 14$

- Ⓐ NOTE: TO OBTAIN THE INDICES FOR A SPECIFIC
- Ⓐ INDEX ORIGIN, ADD:

$\Box IO \leftarrow 1: LB \leftarrow (\sim \Box IO) + \dots$

$\Box IO \leftarrow 0: LB \leftarrow (-\Box IO) + \dots$

ALTERNATE IMPLEMENTATIONS:

FIRST: $LB \leftarrow (V \neq -1+(1+0\text{p}V), V) / \text{ip}V$

LAST: $UB \leftarrow (V \neq 1+V, 1+0\text{p}V) / \text{ip}V$

- Ⓐ THESE CAN BE SIMPLIFIED AS FOLLOWS:

NUMERIC V

CHARACTER V

FIRST: $LB \leftarrow (V \neq -1+0, V) / \text{ip}V \quad LB \leftarrow (V \neq -1+' ', V) / \text{ip}V$

LAST: $UB \leftarrow (V \neq 1+V, 0) / \text{ip}V \quad UB \leftarrow (V \neq 1+V, ' ') / \text{ip}V$

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FINDING INDICES OF ELEMENTS OF A VECTOR V

FINDING THE BOUNDARY INDICES OF THE FIELDS OF V (CONTD)

WHEN THERE ARE NO FIELD DELIMITERS (CONTD)

TYPE 2: WHEN V CONTAINS FIELDS OF IDENTICAL ELEMENTS (CONTD)

- Ⓐ CAUTION: 1ST AND LAST ELEMENTS OF V MUST BE DIFFERENT TO USE THE FOLLOWING IMPLEMENTATIONS

FIRST: $LB \leftarrow (V \neq -1 \phi V) / \wp V$

LAST: $UB \leftarrow (V \neq 1 \phi V) / \wp V$

WHEN THE FIELD DELIMITER IS Q

FIRST ELEMENTS: $LB \leftarrow (1, V=Q) / \wp V$

LAST ELEMENTS: $UB \leftarrow -1 + ((V=Q), 1) / \wp V$

- Ⓐ ASSUMES THAT V CONTAINS NO LEADING OR TRAILING DELIMITERS Q, UNLESS IT HAS EMPTY FIELDS.

- Ⓐ TO PRODUCE AN $N \times 2$ MATRIX "FB" WHERE EACH ROW
- Ⓐ CONTAINS THE BOUNDARY INDICES OF A FIELD,
- Ⓐ ENTER: $FB \leftarrow LB, [\square IO+0.5] UB$

EXAMPLE: $V \leftarrow [55.55 \ 59.55 \ 59.59 \ 50.50 \ 50.59 \ 90.09]$
 $Q \leftarrow []$

RESULT: $LB: 1 \ 7 \ 13 \ 19 \ 25 \ 31 \quad [\square IO \leftarrow 1]$
 $UB: 5 \ 11 \ 17 \ 23 \ 29 \ 35$

- Ⓐ ALTERNATE IMPLEMENTATIONS:

FIRST: $LB \leftarrow (U=Q) / \wp U \leftarrow Q, V$

LAST: $UB \leftarrow -1 + (U=Q) / \wp U \leftarrow V, Q$

SHIFTING A VECTOR V

SHIFTING N POSITIONS WITHOUT CHANGING THE LENGTH OF V

WITH WRAP-AROUND (ROTATING)

RIGHT: $V \leftarrow (-N) \phi V$

LEFT: $V \leftarrow N \phi V$

EXAMPLE: $V \leftarrow 10$
 $N \leftarrow 3$

RESULT: $R: \begin{matrix} 8 & 9 & 10 & 1 & 2 & 3 & 4 & 5 & 6 & 7 \end{matrix}$
 $L: \begin{matrix} 4 & 5 & 6 & 7 & 8 & 9 & 10 & 1 & 2 & 3 \end{matrix}$

a NOTE: USING ONLY $V \leftarrow N \phi V$

a LEFT $\leftrightarrow N > 0$ AND RIGHT $\leftrightarrow N < 0$

WITHOUT WRAP-AROUND

a PAD-ELEMENT WILL BE 0 FOR NUMBERS, BLANKS FOR CHARS

RIGHT: $V \leftarrow (-\rho V) \uparrow (-N) \downarrow V$

LEFT: $V \leftarrow (\rho V) \uparrow N \downarrow V$

EXAMPLE: $V \leftarrow 10$
 $N \leftarrow 4$

RESULT: $R: \begin{matrix} 0 & 0 & 0 & 0 & 1 & 2 & 3 & 4 & 5 & 6 \end{matrix}$
 $L: \begin{matrix} 5 & 6 & 7 & 8 & 9 & 10 & 0 & 0 & 0 & 0 \end{matrix}$

SHIFTING A VECTOR V

CENTERING V

WHEN THE FILL-ELEMENT IS Q

$V \leftarrow (\lceil 0.5 \times (B \downarrow 1) - (\phi B \leftarrow V \neq Q) \downarrow 1 \rceil) \phi V$

EXAMPLE: $V \leftarrow '---AB-C---D--E-----'$
 $Q \leftarrow '-'$

RESULT: $----AB-C---D--E-----$

SHIFTING A VECTOR V

CENTERING V

WITHIN A FIELD OF PAD-ELEMENTS OF WIDTH W

$$W \uparrow (-\lfloor (W+\rho V) \div 2 \rfloor) \uparrow V$$

• OMIT THE "W↑" IF DO NOT NEED RESULT IN FULL WIDTH W

EXAMPLE: $V \leftarrow 'TABLE OF CONTENTS'$
 $W \leftarrow 30$

RESULT: | TABLE OF CONTENTS |

• ALTERNATE IMPLEMENTATIONS:

$$W \uparrow ((\lceil 0.5 \times W - \rho V \rceil) - W) \uparrow V$$

$$W \uparrow ((\lfloor 0.5 \times W - \rho V \rfloor) \rho Q), V \quad [Q \leftarrow 0 \text{ OR } Q \leftarrow ' ']$$

SHIFTING A VECTOR V

CENTERING V

COMPRESSING THE FILL-ELEMENT Q TO THE SIDES

$V \leftarrow (\lceil 0.5 \times + / \sim B \rceil) \phi V [\Delta B \leftarrow V \neq Q]$

EXAMPLE: $V \leftarrow ! \circ \circ A \circ \circ \circ B C \circ D \circ \circ E F \circ \circ \circ \circ G !$
 $Q \leftarrow ! \circ !$

RESULT: $\circ \circ \circ \circ \circ ABCDEFG \circ \circ \circ \circ \circ$

A ALTERNATE IMPLEMENTATION:

$V \leftarrow (\lceil 0.5 \times + / \sim B \rceil) \phi (-\rho V) \uparrow ((\rho V) \rho Q), (B \leftarrow V \neq Q) / V$

SHIFTING A VECTOR V

RIGHT-JUSTIFYING V

WHEN THE FILL-ELEMENT IS Q

$V \leftarrow (\square I O - (Q \neq \phi V) \downarrow 1) \phi V$

$\square I O \leftarrow 1 : \quad V \leftarrow (1 - (Q \neq \phi V) \downarrow 1) \phi V$
 $\square I O \leftarrow 0 : \quad V \leftarrow (- (Q \neq \phi V) \downarrow 1) \phi V$

$\text{a THE COMPLEMENT IS: } \quad V \leftarrow (\square I O - (Q = \phi V) \downarrow 0) \phi V$

EXAMPLE: $V \leftarrow ! * * * A * B B * * C C C * * * * *$
 $Q \leftarrow ! * !$

RESULT: $* * * * * * * A * B B * * C C C$

$\text{a ALTERNATE IMPLEMENTATIONS:}$

$V \leftarrow ((\neg 1 \uparrow (V \neq Q) / \downarrow \rho V) + \sim \square I O) \phi V$

$V \leftarrow (1 - (V = Q) \downarrow 1) \phi V \quad **$

$V \leftarrow (- + / \wedge \backslash Q = \phi V) \phi V$

$\text{a NOTE: IF } "Q" \text{ IS A VECTOR OF DIFFERENT FILL-ELEMENTS,}$
 $\text{a REPLACE } "V \neq Q" \text{ WITH } "\sim V \in Q" \text{ AND } "Q \neq \phi V" \text{ WITH } "\sim (\phi V) \in Q"$

$** \text{ ADAPTED FROM (1) THE APL IDIOM LIST}$

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SHIFTING A VECTOR V

RIGHT-JUSTIFYING V

WHEN THE FILL-ELEMENT IS Q (CONTD)

a SPECIAL CASE IMPLEMENTATION:

- a WHEN V IS LEFT-JUSTIFIED AND THERE ARE NO EMBEDDED FILL-ELEMENTS Q

$$V \leftarrow (+ / V \neq Q) \phi V \quad OR \quad V \leftarrow (V + . \neq Q) \phi V$$

EXAMPLE: $V \leftarrow 'A L A S K A * * * * *'$
 $Q \leftarrow ' * '$

RESULT: $* * * * * A L A S K A$

b ALTERNATE IMPLEMENTATION:

$$V \leftarrow ((V \sqcup Q) - \square I O) \phi V$$

SHIFTING A VECTOR V

RIGHT-JUSTIFYING V

WITHIN A FIELD OF PAD-ELEMENTS OF WIDTH W

$(-W) \uparrow V$

A NOTE: IF $W < pV$, V WILL BE TRUNCATED ON THE LEFT

EXAMPLE: $V \leftarrow 17$
 $W \leftarrow 12$

RESULT: 0 0 0 0 0 1 2 3 4 5 6 7

A NOTE: THE FORMAT FUNCTION " \$" CAN ALSO BE USED TO
RIGHT-JUSTIFY THE CHARACTER RESULT WHEN FORMATTING
NUMBERS

A ALTERNATE IMPLEMENTATION:

$(-W) \uparrow (W_p Q), V$ [$Q \leftarrow 0$ OR $Q \leftarrow ' '$]

SHIFTING A VECTOR V

RIGHT-JUSTIFYING V

COMPRESSING THE FILL-ELEMENT Q LEFT

$V \leftarrow V[\Delta V \neq Q]$

EXAMPLE: $V \leftarrow ! * * * A * B B * * C C C * * * * !$
 $Q \leftarrow ! * !$

RESULT: $***** * * * * * * A B B C C C$

A ALTERNATE IMPLEMENTATIONS:

$V \leftarrow (B/V), (\sim B \leftarrow V = Q) / V$

$V \leftarrow ((+/ \sim B) \rho Q), (B \leftarrow V \neq Q) / V$

$V \leftarrow (-\rho V) \uparrow ((\rho V) \rho Q), (V \neq Q) / V$

A ALTERNATE IMPLEMENTATION, WHEN Q IS THE PAD-ELEMENT:

$V \leftarrow (-\rho V) \uparrow (V \neq Q) / V$

EXAMPLE: $V \leftarrow 0 \ 0 \ 1 \ 0 \ 2 \ 3 \ 0 \ 0 \ 4 \ 0$
 $Q \leftarrow 0$

RESULT: 0 0 0 0 0 0 1 2 3 4

SHIFTING A VECTOR V

LEFT-JUSTIFYING V

WHEN THE FILL-ELEMENT IS Q

$$V \leftarrow (((V \neq Q) \downarrow 1) - \square I O) \phi V$$

$$\begin{aligned} \square I O \leftarrow 1: \quad & V \leftarrow (((V \neq Q) \downarrow 1) - 1) \phi V \\ \square I O \leftarrow 0: \quad & V \leftarrow ((V \neq Q) \downarrow 1) \phi V \end{aligned}$$

A THE COMPLEMENT IS: $V \leftarrow (((V = Q) \downarrow 0) - \square I O) \phi V$

EXAMPLE: $V \leftarrow ! * * * A * B B * * C C C * * * * *$
 $Q \leftarrow ! * !$

RESULT: $A * B B * * C C C * * * * * *$

A ALTERNATE IMPLEMENTATIONS:

$$V \leftarrow ((1 \uparrow (V \neq Q) / 1 \rho V) - \square I O) \phi V$$

$$V \leftarrow (+ / \wedge \backslash V = Q) \phi V$$

$$V \leftarrow (((Q = \phi V) \downarrow 1) - 1) \phi V$$

A NOTE: IF " Q " IS A VECTOR OF DIFFERENT FILL-ELEMENTS,
A REPLACE " $V \neq Q$ " WITH " $\sim V \in Q$ " AND " $Q \neq \phi V$ " WITH " $\sim (\phi V) \in Q$ "

(CONT'D ON NEXT PAGE)

SHIFTING A VECTOR V

LEFT-JUSTIFYING V

WHEN THE FILL-ELEMENT IS Q (CONTD)

A SPECIAL CASE IMPLEMENTATION:

- A WHEN V IS RIGHT-JUSTIFIED AND THERE ARE NO EMBEDDED FILL-ELEMENTS Q

$V \leftarrow (- + / V \neq Q) \phi V$ OR $V \leftarrow (- V + . \neq Q) \phi V$

EXAMPLE: $V \leftarrow '*****ALASKA'$
 $Q \leftarrow ' * '$

RESULT: ALASKA*****

SHIFTING A VECTOR V

LEFT-JUSTIFYING V

WITHIN A FIELD OF PAD-ELEMENTS OF WIDTH W

$W \uparrow V$

A NOTE: IF $W < pV$, V WILL BE TRUNCATED ON THE RIGHT

EXAMPLE: $V \leftarrow 17$
 $W \leftarrow 12$

RESULT: 1 2 3 4 5 6 7 0 0 0 0 0

A ALTERNATE IMPLEMENTATION:

$W \uparrow V, W \rho Q$ [$Q \leftarrow 0$ OR $Q \leftarrow ' '$]

SHIFTING A VECTOR V

LEFT-JUSTIFYING V

COMPRESSING THE FILL-ELEMENT Q RIGHT

$V \leftarrow V[\Psi V \neq Q]$

EXAMPLE: $V \leftarrow '***A*BB**CCC*****'$
 $Q \leftarrow ' * '$

RESULT: $ABBCCC*****$

A ALTERNATE IMPLEMENTATIONS:

$V \leftarrow (B/V), (\sim B \leftarrow V \neq Q) / V$

$V \leftarrow (B/V), (+/\sim B \leftarrow V \neq Q) \rho Q$

$V \leftarrow (\rho V) \uparrow ((V \neq Q) / V), (\rho V) \rho Q$

A ALTERNATE IMPLEMENTATION, WHEN Q IS THE PAD-ELEMENT:

$V \leftarrow (\rho V) \uparrow (V \neq Q) / V$

EXAMPLE: $V \leftarrow 0 0 1 0 2 3 0 0 4 0$
 $Q \leftarrow 0$

RESULT: $1 2 3 4 0 0 0 0 0 0$

SHIFTING A VECTOR V

REVERSING THE POSITIONS OF THE ELEMENTS OF V

REVERSING THE ELEMENTS WITH INDICES I

$V[\phi I] \leftarrow V[I]$

EXAMPLE: $V \leftarrow 13 \ 56 \ 35 \ 44 \ 21 \ 60 \ 78$
 $I \leftarrow 2 \ 5 \quad [I \leftarrow 10 \leftarrow 1]$

RESULT: 13 21 35 44 56 60 78

A NOTE: IF $2 < \rho I$, THIS WILL REVERSE THE POSITIONS OF
A THE GROUP OF ELEMENTS

SHIFTING A VECTOR V

REVERSING THE POSITIONS OF THE ELEMENTS OF V

REVERSING THE ELEMENTS WITHIN EACH FIELD OF V

- Ⓐ MUST FIRST GENERATE A LOGICAL VECTOR P DEFINING THE FIELD PARTITION OF V, WITH A 1-BIT FOR THE 1ST ELEMENT OF EACH FIELD OF V AND 0'S OTHERWISE (SEE SECTION "GENERATING A LOGICAL VECTOR").
- Ⓐ ALSO $\rho P \leftrightarrow \rho V$
- Ⓐ CAUTION: ANY FIELD DELIMITERS MUST BE DELETED FROM V

$V \leftarrow V[\phi\Psi + \setminus P]$ **

EXAMPLE: $V \leftarrow 'ABCDEFGHIJ'$
 $P \leftarrow 1\ 0\ 0\ 1\ 1\ 0\ 0\ 0\ 1\ 0$

RESULT: CBADEHGFJI

** ADAPTED FROM (2) BOOLEAN FUNCTIONS AND TECHNIQUES

SORTING A VECTOR V

SORTING A NUMERIC VECTOR

IN ASCENDING ORDER

$V \leftarrow V[\Delta V]$

- Ⓐ CAUTION: BEFORE SORTING, MAY HAVE TO USE " $V \leftarrow , V$ "
- Ⓐ TO ENSURE THAT V IS A VECTOR

EXAMPLE: $V \leftarrow 77 \ 29 \ 42 \ 3 \ 18 \ 81$

RESULT: 3 18 29 42 77 81

- Ⓐ NOTE: CAN USE " $I \leftarrow \Delta V$ " TO SORT ANOTHER VECTOR " W " WHOSE
- Ⓐ ELEMENTS CORRESPOND TO V , I.E.: $W \leftarrow W[I]$

IN DESCENDING ORDER

$V \leftarrow V[\Psi V]$

RESULT: 81 77 42 29 18 3

- Ⓐ NOTE: IN SUBSEQUENT TECHNIQUES, A DESCENDING SORT
- Ⓐ MAY BE OBTAINED BY SUBSTITUTING " Ψ " FOR " Δ "

IN EITHER ASCENDING OR DESCENDING ORDER

$V \leftarrow V[\Delta V \times T]$ **

- Ⓐ FOR ASCENDING SORT, SET " $T \leftarrow 1$ "; FOR DESCENDING, " $T \leftarrow -1$ "

EXAMPLE: $T \leftarrow -1$

RESULT: 81 77 42 29 18 3

** ADAPTED FROM (1) THE APL IDIOM LIST

SORTING A VECTOR V

SORTING A NUMERIC VECTOR

SORTING THE ELEMENTS OF V WITHIN THE FIELDS OF V

A MUST FIRST GENERATE A LOGICAL VECTOR P DEFINING THE
A FIELD PARTITION OF V, WITH A 1-BIT FOR THE 1ST
A ELEMENT OF EACH FIELD OF V AND 0'S OTHERWISE
A (SEE SECTION "GENERATING A LOGICAL VECTOR").
A ALSO $\rho P \leftrightarrow \rho V$

A CAUTION: ANY FIELD DELIMITERS MUST BE DELETED FROM V

IN ASCENDING ORDER

$V \leftarrow V[S[\Delta(+\setminus P)[S \leftarrow \Delta V]]]$

**

EXAMPLE: $V \leftarrow 10\ 9\ 8\ 7\ 6\ 5\ 4\ 3\ 2\ 1$
 $P \leftarrow 1\ 0\ 0\ 1\ 1\ 0\ 0\ 0\ 1\ 0$

RESULT: 8 9 10 7 3 4 5 6 1 2

A ALTERNATE IMPLEMENTATION, FOR NUMBERS > 0:

$V \leftarrow V[\Delta V++\setminus P \times \lceil /V]$

A THE SORT INDICES "WITHIN EACH FIELD" CAN BE
A GENERATED VIA:

$I \leftarrow \square IO + S[\Delta(+\setminus P)[S \leftarrow \Delta V]] - \lceil \setminus P \times \lceil \rho P$

**

RESULT: 3 2 1 1 4 3 2 1 2 1 [$\square IO \leftarrow 1$]

** ADAPTED FROM (2) BOOLEAN FUNCTIONS AND TECHNIQUES
(CONT'D ON NEXT PAGE)

SORTING A VECTOR V

SORTING A NUMERIC VECTOR

SORTING THE ELEMENTS OF V WITHIN THE FIELDS OF V (CONTD)

IN DESCENDING ORDER

$V \leftarrow V[S[\Delta(+\setminus P)[S \leftarrow \Psi V]]]$

**

EXAMPLE: $V \leftarrow 1 \ 2 \ 3 \ 4 \ 5 \ 6 \ 7 \ 8 \ 9 \ 10$
 $P \leftarrow 1 \ 0 \ 0 \ 1 \ 1 \ 0 \ 0 \ 0 \ 1 \ 0$

RESULT: 3 2 1 4 8 7 6 5 10 9

A ALTERNATE IMPLEMENTATION, FOR NUMBERS > 0:

$V \leftarrow V[\Psi V++\setminus P \times -\lceil /V]$

A LIKEWISE THE SORT INDICES "WITHIN THE FIELDS" ARE:

$I \leftarrow \square IO + S[\Delta(+\setminus P)[S \leftarrow \Psi V]] - \lceil \setminus P \times \iota_0 P$ **

RESULT: 2 1 0 0 3 2 1 0 1 0 [$\square IO \leftarrow 0$]

** ADAPTED FROM (2) BOOLEAN FUNCTIONS AND TECHNIQUES

SORTING A VECTOR V

SORTING A NUMERIC VECTOR

DETERMINING THE RANK-ORDER R OF THE ELEMENTS OF V

ASCENDING RANK-ORDER

$R \leftarrow \Delta \Delta V$

- Ⓐ $\rho R \leftrightarrow \rho V$
- Ⓐ $R[I]$ IS THE RANK OF $V[I]$ IN V , I.E., THE INDEX OF $V[I]$ IN A SORTED V

Ⓐ NOTE: THIS IS A "KERNEL" APL OPERATION

EXAMPLE: $V \leftarrow 148 149 152 157 153 160 143$
 $V \leftarrow V, 137 146 151 155 147 150 145$

RESULT: 6 7 10 13 11 14 2 1 4 9 12 5 8 3

Ⓐ ALTERNATE IMPLEMENTATION:

$R \leftarrow V[\Delta V] \downarrow V$

DESCENDING RANK-ORDER

$R \leftarrow \Delta \Psi V$

RESULT: 9 8 5 2 4 1 13 14 11 6 3 10 7 12

Ⓐ ALTERNATE IMPLEMENTATION:

$R \leftarrow V[\Psi V] \downarrow V$

SORTING A VECTOR V

SORTING A CHARACTER VECTOR

A NOTES:

- A 1. NON-NUMERIC DATA MUST BE ENCODED AS NUMBERS IN ORDER TO BE SORTED.
- A 2. THE NUMERIC SORT OPERATIONS CAN BE MODIFIED FOR SORTING A CHARACTER VECTOR V BY REPLACING " ΔV " WITH THE "KERNEL" APL OPERATION " $\$SSEQ \downarrow V$ " (SEE BELOW FOR POSSIBLE "SSEQ"). LIKEWISE FOR Ψ .
- A 3. THE SORT SEQUENCE (SSEQ) IS USER-DEFINED. "BLANK" MUST BE POSITIONED WHERE APPROPRIATE.
- A 4. CAUTION: $\Box AV$ IS SYSTEM DEPENDENT. THE FOLLOWING SORT SEQUENCES WITH $\Box AV$ ARE FOR APLSV.

A POSSIBLE SORT SEQUENCES (SSEQ):

- A $SSEQ \leftarrow 'ABCD...WXYZ\Delta 0123456789'$ - EXPLICIT DEFINITION
- A $SSEQ \leftarrow \Box AV$ - SYSTEM DEFINITION: LETTERS (PLAIN AND underscored), NUMBERS, BLANK
- A $SSEQ \leftarrow ' ', \Box AV$ - BLANK, LETTERS, NUMBERS
- A $SSEQ \leftarrow (64 \uparrow 86 \downarrow \Box AV), ' \Box '$ - LETTERS, NUMBERS, SPECIAL CHARS (SEQUENCE FOR LABELS)
- A OR ANY OTHER SEQUENCE OF ANY CHARACTERS.

MOVING CHARACTERS NOT IN THE SORT SEQUENCE TO END OF V

$V \leftarrow V[\$SSEQ \downarrow V]$

EXAMPLE: $V \leftarrow 'PROBLEM DEFINITION: (I \div J) + C \Gamma 52'$
 $SSEQ \leftarrow 'ABCDEFGHIJKLMNPQRSTUVWXYZ 0123456789'$

RESULT: BCDEEFFIIIIJLMNNOOPRT 25:(\div) + Γ

A NOTE: SUBSTITUTE " Ψ " FOR " Δ " TO OBTAIN A DESCENDING SORT

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SORTING A VECTOR V

SORTING A CHARACTER VECTOR (CONTD)

DELETING CHARACTERS NOT IN THE SORT SEQUENCE

$V \leftarrow V[(I[J] < \square I0 + \rho SSEQ) / J \leftarrow \Delta I \leftarrow SSEQ \cup V]$

RESULT: BCDEEFFIIIIJLMNNOOPRT 25

A ALTERNATE IMPLEMENTATION:

$V \leftarrow V[\Delta SSEQ \cup V \leftarrow (V \in SSEQ) / V]$

SORTING A VECTOR V

MERGING 2 NUMERIC VECTORS IN ASCENDING ORDER

$V \leftarrow V[\wedge V \leftarrow V_1, V_2]$

EXAMPLE: $V_1 \leftarrow 53 \ 25 \ 98 \ 33 \ 86$
 $V_2 \leftarrow 42 \ 79 \ 17 \ 101 \ 64$

RESULT: 17 25 33 42 53 64 79 86 98 101

A NOTE: SUBSTITUTE " \vee " FOR " \wedge " TO OBTAIN A DESCENDING
MERGE

SORTING A VECTOR V

MERGING 2 VECTORS USING THE PATTERN IN LOGICAL VECTOR L

$V \leftarrow (V1, V2)[\Delta \Psi L]$

- Ⓐ 1's IN L DESIGNATE POSITIONS FOR ELEMENTS OF V1,
- Ⓐ 0's FOR V2
- Ⓐ $\rho L \leftrightarrow \rho V1, V2$

EXAMPLE: $V1 \leftarrow 'ACDG'$
 $V2 \leftarrow 'BEF'$
 $L \leftarrow 1 0 1 1 0 0 1$

RESULT: ABCDEFG

A ALTERNATE IMPLEMENTATIONS:

$V \leftarrow (V2, V1)[\Delta \Delta L]$

$V \leftarrow L \setminus V1$
 $V[(\sim L) / \circ \rho V] \leftarrow V2$ **

** ADAPTED FROM (1) THE APL IDIOM LIST

SORTING A VECTOR V

MERGING 2 VECTORS OF SAME LENGTH IN ALTERNATING POSITIONS

$V3 \leftarrow, V1, [\square IO + 0.5] V2$

$\square IO \leftarrow 1: V3 \leftarrow, V1, [1.5] V2$
 $\square IO \leftarrow 0: V3 \leftarrow, V1, [0.5] V2$

A NOTE: AXIS-NUMBER DECIMAL-PART IS A DECIMAL VALUE
A BETWEEN 0 AND 1; "0.5" SHOWN HERE

EXAMPLE: $V1 \leftarrow 1 \ 3 \ 5 \ 7 \ 9$
 $V2 \leftarrow 2 \ 4 \ 6 \ 8 \ 10$

RESULT: 1 2 3 4 5 6 7 8 9 10

COMPUTING VALUES FROM A VECTOR V

DETERMINING THE WIDTHS W OF THE FIELDS OF V

WHEN THERE ARE NO FIELD DELIMITERS

A FROM FIELDS OF IDENTICAL ELEMENTS

$$W \leftarrow I - 1 + 0, I \leftarrow (\sim \square IO) + (((1 + V) \neq -1 + V), 1) / \wp V$$

A "I" CONTAINS THE ORIGIN-1 INDICES OF THE LAST
A ELEMENTS IN EACH FIELD

A NOTE: MAY HAVE TO SORT V FIRST TO PRODUCE THE FIELDS

EXAMPLE: $V \leftarrow 'BBADDCC'$

RESULT: 2 1 4 3

WHEN THE FIELD DELIMITER IS Q

$$W \leftarrow (I, 1 + \wp V) - 1 + 0, I \leftarrow (\sim \square IO) + (V = Q) / \wp V$$

A ASSUMES THAT V CONTAINS NO TRAILING DELIMITERS Q
A (UNLESS THERE IS AN "EMPTY" FIELD)

EXAMPLE: VECTOR OF FIELDS DELIMITED BY COMMAS

$V \leftarrow 'KR235,RT1,32,TEST VARIATIONS,,9/27/78'$
 $Q \leftarrow ','$

RESULT: 5 3 2 15 0 7

A ALTERNATE IMPLEMENTATIONS:

$$W \leftarrow I - 1 + -1 + 0, I \leftarrow (\sim \square IO) + ((V = Q), 1) / \wp V$$

$$W \leftarrow I - 1 + -1 + 0, I \leftarrow (\sim \square IO) + (U = Q) / \wp U \leftarrow V, Q$$

COMPUTING VALUES FROM A VECTOR V

SUMMING SETS OF ELEMENTS OF V

SETS OF ELEMENTS SORTED INTO FIELDS

A SETS OF IDENTICAL ELEMENTS

$S \leftarrow W -^{-} 1 \downarrow 0, W \leftarrow (V \neq 1 \downarrow V, 0) / + \setminus V$

A CAUTION: ANY FIELD DELIMITERS MUST BE DELETED FROM V

EXAMPLE: $V \leftarrow 2 \ 2 \ 5 \ 5 \ 5 \ 4 \ 1 \ 3 \ 3 \ 3$

RESULT: 4 15 4 1 9

A TO SUM THE ELEMENTS OF ANOTHER VECTOR "X" WHOSE ELEMENTS CORRESPOND TO V, SUBSTITUTE "+\setminus X" FOR "+\setminus V"

A ALTERNATE IMPLEMENTATIONS:

$S \leftarrow W -^{-} 1 \downarrow 0, W \leftarrow (((1 \downarrow V) \neq -1 \downarrow V), 1) / + \setminus V$

$S \leftarrow (V \neq 1 \downarrow V, 0) / V \times + / V \circ . = V$

COMPUTING VALUES FROM A VECTOR V

SUMMING SETS OF ELEMENTS OF V

SETS OF ELEMENTS NOT IN FIELDS

TYPE 1: SETS OF IDENTICAL ELEMENTS

$S \leftarrow V + . \times V \circ . = ((\wp V) = V \wp V) / V$ **

EXAMPLE: $V \leftarrow 2 \ 5 \ 4 \ 1 \ 3 \ 2 \ 5 \ 3 \ 5 \ 3$

RESULT: 4 15 4 1 9

TYPE 2: SETS DEFINED BY VECTOR I

$S \leftarrow V + . \times I \circ . = ((\wp I) = I \wp I) / I$ **

- Ⓐ VECTOR "I" DEFINES THE SETS IN V BY IDENTICAL ELEMENTS.
- Ⓐ ALL ELEMENTS OF V WHOSE CORRESPONDING ELEMENTS IN I
- Ⓐ ARE THE SAME COMPOSE A SET; $\wp V \leftrightarrow \wp I$
- Ⓐ $\wp S \leftrightarrow$ THE NUMBER OF SETS DEFINED BY I
- Ⓐ IF "I" CONSISTS OF POSITIVE INTEGERS, AND ALL INTEGERS
- Ⓐ OF " $i \lceil / I$ " OCCUR IN I, THEN THIS TECHNIQUE CAN BE
- Ⓐ SIMPLIFIED TO:

$S \leftarrow V + . \times I \circ . = i \lceil / I$ **

EXAMPLE: $V \leftarrow 72 \ 78 \ 94 \ 83 \ 85 \ 83 \ 76 \ 91 \ 75$
 $I \leftarrow 22 \ 44 \ 11 \ 55 \ 11 \ 22 \ 55 \ 55 \ 22$

RESULT: 230 78 179 250

** ADAPTED FROM (1) THE APL IDIOM LIST

COMPUTING VALUES FROM A VECTOR V

DETERMINING THE PAIRWISE DIFFERENCES D IN V

$D \leftarrow (1 \downarrow V) -^{\top} 1 \downarrow V$

Ⓐ $\rho D \leftrightarrow (\rho V) - 1$

EXAMPLE: $V \leftarrow 1 \ 4 \ 9 \ 16 \ 25 \ 36 \ 49 \ 64$

RESULT: 3 5 7 9 11 13 15

Ⓐ ALTERNATE IMPLEMENTATION:

$D \leftarrow 1 \downarrow V -^{\top} 1 \phi V$

Ⓐ TO INCLUDE THE 1ST ELEMENT OF V IN THE RESULT [$\rho D \leftrightarrow \rho V$]:

$D \leftarrow V -^{\top} 1 \downarrow 0, V$

RESULT: 1 3 5 7 9 11 13 15

Ⓐ NOTE: THESE ARE "KERNEL" APL OPERATIONS

COMPUTING VALUES FROM A VECTOR V

COMPUTING THE AVERAGE OF THE VALUES IN V

$AVG \leftarrow (+/V) \div 1 \Gamma \rho , V$ **

• WILL PROCESS A SCALAR AND AN EMPTY VECTOR ($0 = \rho V$)

EXAMPLE: $V \leftarrow 86 \ 81 \ 92 \ 73 \ 68 \ 89$

RESULT: 81.5

** ADAPTED FROM (1) THE APL IDIOM LIST

COMPUTING VALUES FROM A VECTOR V

PERFORMING ARITHMETIC SCAN OPERATIONS ON V

• THE SIGNIFICANCE OF CERTAIN SCAN OPERATIONS IS AS
• FOLLOWS [ADAPTED FROM (1) THE APL IDIOM LIST]:

EXAMPLE: $V \leftarrow 1 \ 3 \ 0 \ 0 \ 5 \ 1 \ 0 \ 2$

$+ \backslash V$ = PROGRESSIVE SUM: 1 4 4 4 9 10 10 12

$\times \backslash V$ = PROGRESSIVE PRODUCT: 1 3 0 0 0 0 0 0

$\lceil \backslash V$ = PROGRESSIVE MAXIMA: 1 3 3 3 5 5 5 5

$\lfloor \backslash V$ = PROGRESSIVE MINIMA: 1 1 0 0 0 0 0 0

• SPECIAL CASE:

$- \backslash i N$ = ALTERNATING SERIES: $[N \leftarrow 7] \quad 1 \ -1 \ 2 \ -2 \ 3 \ -3 \ 4$

• ALTERNATE IMPLEMENTATIONS FOR "PLUS-SCAN", WITHOUT
• USING THE SCAN OPERATOR " $+ \backslash$ ":

$S \leftarrow V + . \times I \circ . \leq I \leftarrow 1 \rho V$

$D \leftarrow (- \rho T \leftarrow - \rho S \leftarrow V) \uparrow -1$
 $LP : S \leftarrow S + T \uparrow D \downarrow S$
 $\rightarrow (T < -1 \uparrow D \leftarrow 2 \times D) / LP$ **

** ADAPTED FROM (3) USE AND MISUSE OF APL

COMPUTING VALUES FROM A VECTOR V

PERFORMING LOGICAL SCAN OPERATIONS ON V

• THE SIGNIFICANCE OF CERTAIN SCAN OPERATIONS IS AS
• FOLLOWS [ADAPTED FROM (1) THE APL IDIOM LIST]:

EXAMPLE: $V \leftarrow 0\ 0\ 0\ 0\ 1\ 0\ 1\ 1\ 0\ 1\ 0$

$\vee \setminus V$ = ALL 1'S STARTING WITH THE FIRST (LEFTMOST) 1:

0 0 0 0 1 1 1 1 1 1 1

$\langle \setminus V$ = ALL 0'S EXCEPT THE FIRST (LEFTMOST) 1:

0 0 0 0 1 0 0 0 0 0 0

$\geq \setminus V$ = ALTERNATING 0'S AND 1'S UNTIL FIRST 1; THEN
ALL SAME AS LAST DIGIT:

0 1 0 1 1 1 1 1 1 1 1

$= \setminus V$ = ALTERNATING FIELDS OF 1'S AND 0'S, CHANGING
TO THE COMPLEMENT AS OF EACH 0. FIRST FIELD
OF 0'S OCCURS STARTING WITH FIRST 0 [0'S IN V
DESIGNATE 1ST ELEMENTS OF FIELDS IN RESULT]:

0 1 0 1 1 0 0 0 1 1 0

EXAMPLE: $V \leftarrow 1\ 1\ 0\ 0\ 1\ 0\ 0\ 0\ 1\ 0\ 1\ 0$

$\wedge \setminus V$ = ALL 0'S STARTING WITH THE FIRST (LEFTMOST) 0:

1 1 1 0 0 0 0 0 0 0 0 0

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COMPUTING VALUES FROM A VECTOR V

PERFORMING LOGICAL SCAN OPERATIONS ON V (CONTD)

EXAMPLE: $V \leftarrow 1\ 1\ 1\ 0\ 0\ 1\ 0\ 0\ 0\ 1\ 0\ 1\ 0$ (CONTD)

$\leq \backslash V$ = ALL 1's EXCEPT THE FIRST (LEFTMOST) 0:

1 1 1 0 1 1 1 1 1 1 1 1 1 1

$\rightarrow \backslash V = ALTERNATING\ 1'S\ AND\ 0'S\ UNTIL\ FIRST\ 0;\ THEN$
 $ALL\ SAME\ AS\ LAST\ DIGIT:$

1 0 1 1 1 1 1 1 1 1 1 1 1 1

$\neq \backslash V$ = ALTERNATING FIELDS OF 1'S AND 0'S, CHANGING TO THE COMPLEMENT AS OF EACH 1. FIRST FIELD OF 1'S OCCURS STARTING WITH FIRST 1 [1'S IN V DESIGNATE 1ST ELEMENTS OF FIELDS IN RESULT];

1 0 1 1 1 0 0 0 0 1 1 0 0

A REPETITIVE EXECUTION OF " \neq " ON A LOGICAL VECTOR
A WHICH INITIALLY HAS ALL 1'S WILL PRODUCE THE
A FOLLOWING BIT-PATTERNS: **

1111111111111111	○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○
1010101010101010	○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○
1100110011001100	○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○
1000100010001000	○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○
1111000011110000	○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○
1010000010100000	○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○
1100000011000000	○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○
1000000010000000	○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○
1111111100000000	○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○
1010101000000000	○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○
1100110000000000	○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○
1000100000000000	○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○
1111000000000000	○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○
1010000000000000	○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○
1100000000000000	○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○
1000000000000000	○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○

*** ADAPTED FROM (2) BOOLEAN FUNCTIONS AND TECHNIQUES*

REPLACING ELEMENTS OF A VECTOR V

REPLACING ELEMENTS SELECTED BY A TEST

WITH ELEMENT Q

$V[(TEST)/\rho V] \leftarrow Q$

- Ⓐ THE "TEST" MUST PRODUCE A BOOLEAN RESULT (E.G.,
Ⓐ USING A LOGICAL OR RELATIONAL EXPRESSION) WHICH
Ⓐ IS THE SAME LENGTH AS V
- Ⓐ IF $2 \leq \rho Q$, Q MUST CONTAIN THE SAME NUMBER OF ELEMENTS
Ⓐ AS THOSE TO BE REPLACED IN V

EXAMPLE: $V \leftarrow [42 \ -75 \ 0 \ -3 \ 27 \ 0 \ 0 \ -59]$
 $TEST \leftarrow V < 0$
 $Q \leftarrow 0$

RESULT: $42 \ 0 \ 0 \ 0 \ 27 \ 0 \ 0 \ 0$

Ⓐ ALTERNATE IMPLEMENTATION:

$V \leftarrow (\rho V) \rho (TEST) \ominus V, [\Box I0-0.5] Q$

- Ⓐ Q IS A SCALAR OR A VECTOR WHERE $\rho Q \leftrightarrow \rho V$
- Ⓐ WHEN Q IS A VECTOR AND $(\rho Q) < \rho V$, Q MUST BE EXPANDED
Ⓐ TO THE LENGTH OF V, E.G., WITH PAD-ELEMENTS:

$V \leftarrow (\rho V) \rho B \ominus V, [\Box I0-0.5] (B \leftarrow TEST) \setminus Q$

- Ⓐ NOTE: AXIS-NUMBER DECIMAL-PART IS A DECIMAL
Ⓐ VALUE BETWEEN 0 AND 1; "0.5" SHOWN HERE

(CONT'D ON NEXT PAGE)

REPLACING ELEMENTS OF A VECTOR V

REPLACING ELEMENTS SELECTED BY A TEST (CONTD)

WITH ELEMENT Q (CONTD)

A ALTERNATE IMPLEMENTATION, FOR NUMERIC VECTORS:

$V \leftarrow (V \times \sim L) + Q \times L \leftarrow TEST$

EXAMPLE: $V \leftarrow 42 \ -75 \ 0 \ -3 \ 27 \ 0 \ 0 \ -59$
 $TEST \leftarrow V \leq 0$
 $Q \leftarrow 2$

RESULT: 42 2 2 2 27 2 2 2

A SPECIAL CASE IMPLEMENTATIONS, REPLACING 0'S WITH Q

$V \leftarrow V + Q \times V = 0$ **

$V \leftarrow V + (V = 0) \setminus Q$

EXAMPLE: $Q \leftarrow 99$

RESULT: 42 -75 99 -3 27 99 99 -59

** ADAPTED FROM (1) THE APL IDIOM LIST

REPLACING ELEMENTS OF A VECTOR V

REPLACING ELEMENTS SELECTED BY A TEST

WITH THE PAD-ELEMENT (0 OR BLANK)

$V \leftarrow B \setminus (B \leftarrow \sim TEST) / V$

EXAMPLE: REPLACING ' / ' WITH BLANKS

$V \leftarrow '12/31/78'$
 $TEST \leftarrow V = ' / '$

RESULT: 12 31 78

A NOTE: THIS TECHNIQUE ALLOWS FURTHER PROCESSING
A OF V ON THE SAME LINE, IN CONTRAST TO
A REPLACEMENT BY INDEXING

REPLACING ELEMENTS OF A VECTOR V

REPLACING MULTIPLE OCCURRENCES OF AN OLD SUBSTRING OS WITH A NEW SUBSTRING NS

Ⓐ MUST FIRST FIND THE STARTING INDICES I OF THE
Ⓐ OCCURRENCES OF THE OLD SUBSTRING (SEE TECHNIQUES
Ⓐ "FINDING THE STARTING INDICES ..."). THESE
Ⓐ INDICES MUST BE IN ASCENDING ORDER.

Ⓐ THEN COMPUTE THE ADJUSTED STARTING INDICES OF THE
Ⓐ OCCURRENCES OF THE OLD SUBSTRING

$$I \leftarrow (I - \square IO) + ((NI \leftarrow \rho I) - \square IO) \times -(OL \leftarrow \rho OS) - \rho NS$$

$$NI \leftarrow NI + K \leftarrow \square IO - 1$$

$$LP : \rightarrow (NI \leftarrow K \leftarrow K + 1) / 0$$

Ⓐ SUBSTITUTE THE NEW SUBSTRING IN PLACE OF THE OLD ONE

$$V \leftarrow (P \uparrow V), NS, (OL + P \leftarrow I[K]) \downarrow V$$

$$\rightarrow LP$$

EXAMPLE: $V \leftarrow !RV \leftarrow ((\downarrow \rho RV) = RV \downarrow RV) / RV!$
 $OS \leftarrow !RV!$
 $NS \leftarrow !FACTORS!$
 $I \leftarrow 1 \ 8 \ 12 \ 15 \ 19 \quad [\square IO \leftarrow 1]$

RESULT: $FACTORS \leftarrow ((\downarrow \rho FACTORS) = FACTORS \downarrow FACTORS) / FACTORS$

Ⓐ NOTE: IF "NS" IS AN EMPTY STRING, THE OLD STRING IS
Ⓐ DELETED FROM THE VECTOR

Ⓐ ALTERNATE IMPLEMENTATION:

$$D \leftarrow \sim (\downarrow \rho V) \in (I - \square IO) \circ . + \downarrow \rho OS$$
$$R \leftarrow ((\downarrow \rho V) \in I) \circ . \wedge (\rho NS) \rho 1$$
$$V \leftarrow (, D, R) / , V, ((\rho V), \rho NS) \rho NS$$

DELETING ELEMENTS FROM A VECTOR V

DELETING ALL OCCURRENCES OF ELEMENT Q

$V \leftarrow (V \neq Q) / V$

EXAMPLE: *DELETING BLANKS*

$V \leftarrow 'M35, M40, 42.5, TEST, 4/23/78'$
 $Q \leftarrow ''$

RESULT: *M35, M40, 42.5, TEST, 4/23/78*

• ALTERNATE IMPLEMENTATIONS, WHEN Q IS A VECTOR:

$V \leftarrow (\sim V \in Q) / V$

$V \leftarrow (\wedge / V \circ . \neq Q) / V$

EXAMPLE: $V \leftarrow 'M35, M40, 42.5, TEST, 4/23/78'$
 $Q \leftarrow ', ./'$

RESULT: *M35M40425TEST42378*

• NOTE: " $\sim V \in Q$ " IS A "KERNEL" APL OPERATION

DELETING ELEMENTS FROM A VECTOR V

DELETING ALL LEADING OCCURRENCES OF ELEMENT Q

$V \leftarrow ((V \neq Q) \downarrow 1) - \square I O \downarrow V$

$\square I O \leftarrow 1 : V \leftarrow (((V \neq Q) \downarrow 1) - 1) \downarrow V$
 $\square I O \leftarrow 0 : V \leftarrow ((V \neq Q) \downarrow 1) \downarrow V$

• THE COMPLEMENT IS: $V \leftarrow (((V = Q) \downarrow 0) - \square I O) \downarrow V$

• NOTE: “ $((V \neq Q) \downarrow 1) - \square I O$ ” IS A “KERNEL” APL OPERATION

EXAMPLE: DELETING LEADING ZEROES

$V \leftarrow 0 0 0 22 3 0 14 0 0 57 0 0$
 $Q \leftarrow 0$

RESULT: 22 3 0 14 0 0 57 0 0

• ALTERNATE IMPLEMENTATIONS:

$V \leftarrow (V \setminus V \neq Q) / V$

$V \leftarrow (+/\wedge\setminus V = Q) \downarrow V$

$V \leftarrow ((1 \uparrow (V \neq Q) / 1 \rho V) - \square I O) \downarrow V$

$V \leftarrow (((Q = \phi V) \downarrow 1) - 1) \downarrow V$

• NOTE: IF “Q” IS A VECTOR OF DIFFERENT ELEMENTS,
• REPLACE “ $V \neq Q$ ” WITH “ $\sim V \in Q$ ” AND “ $Q \neq \phi V$ ” WITH “ $\sim (\phi V) \in Q$ ”

DELETING ELEMENTS FROM A VECTOR V

DELETING ALL TRAILING OCCURRENCES OF ELEMENT Q

$V \leftarrow (\Box I O - (Q \neq \phi V) \downarrow 1) \downarrow V$

$\Box I O \leftarrow 1 : V \leftarrow (1 - (Q \neq \phi V) \downarrow 1) \downarrow V$
 $\Box I O \leftarrow 0 : V \leftarrow (- (Q \neq \phi V) \downarrow 1) \downarrow V$

a THE COMPLEMENT IS: $V \leftarrow (\Box I O - (Q = \phi V) \downarrow 0) \downarrow V$

a NOTE: " $\Box I O - (Q \neq \phi V) \downarrow 1$ " IS A "KERNEL" APL OPERATION

EXAMPLE: DELETING TRAILING ZEROES

$V \leftarrow 0 \ 0 \ 0 \ 22 \ 3 \ 0 \ 14 \ 0 \ 0 \ 57 \ 0 \ 0$
 $Q \leftarrow 0$

RESULT: 0 0 0 22 3 0 14 0 0 57

a ALTERNATE IMPLEMENTATIONS:

$V \leftarrow (1 - (V = Q) \downarrow 1) \downarrow V$ **

$V \leftarrow ((\neg 1 \uparrow (V \neq Q) / \downarrow \rho V) + \sim \Box I O) \uparrow V$

$V \leftarrow (\phi v \setminus Q \neq \phi V) / V$

$V \leftarrow (- + / \wedge \setminus Q = \phi V) \downarrow V$

a NOTE: IF " Q " IS A VECTOR OF DIFFERENT ELEMENTS,
a REPLACE " $V \neq Q$ " WITH " $\sim V \in Q$ " AND " $Q \neq \phi V$ " WITH " $\sim (\phi V) \in Q$ "

** ADAPTED FROM (1) THE APL IDIOM LIST

DELETING ELEMENTS FROM A VECTOR V

DELETING LEADING AND.TRAILING OCCURRENCES OF ELEMENT Q

$V \leftarrow ((B \downarrow 1) - \square I O) \downarrow (\square I O - (\phi B \leftarrow V \neq Q) \downarrow 1) + V$

$\square I O \leftarrow 1 : V \leftarrow ((B \downarrow 1) - 1) \downarrow (1 - (\phi B \leftarrow V \neq Q) \downarrow 1) + V$
 $\square I O \leftarrow 0 : V \leftarrow (B \downarrow 1) \downarrow (-(\phi B \leftarrow V \neq Q) \downarrow 1) + V$

a THE COMPLEMENT IS: $V \leftarrow ((B \downarrow 0) - \square I O) \downarrow (\square I O - (\phi B \leftarrow V = Q) \downarrow 0) + V$

EXAMPLE: DELETING ZEROES

$V \leftarrow 0 \ 0 \ 0 \ 22 \ 3 \ 0 \ 14 \ 0 \ 0 \ 57 \ 0 \ 0$
 $Q \leftarrow 0$

RESULT: 22 3 0 14 0 0 57

a ALTERNATE IMPLEMENTATIONS:

$V \leftarrow ((1 \uparrow I) - \square I O) \downarrow ((\neg 1 \uparrow I \leftarrow (V \neq Q) / \downarrow \rho V) + \neg \square I O) \uparrow V$

$V \leftarrow ((V \setminus B) \wedge \phi V \setminus \phi B \leftarrow V \neq Q) / V$

DELETING ELEMENTS FROM A VECTOR V

DELETING REDUNDANT OCCURRENCES OF ELEMENT Q

$V \leftarrow (L \vee^{-1} \downarrow 1, L \leftarrow V \neq Q) / V$

A REDUNDANT = THE 2ND, 3RD, ETC., CONTIGUOUS OCCURRENCES

EXAMPLE: DELETING ASTERisks

$V \leftarrow ! * * A * * * * B B * C C C * * * !$
 $Q \leftarrow ! * !$

RESULT: *A*BB*CCC*

A NOTE: BOTH $V \leftarrow (L \vee 1 \phi L \leftarrow V \neq Q) / V$

A AND $V \leftarrow (L \wedge 1 \phi L \leftarrow V = Q) / V$ [THE COMPLEMENT]

A DELETE THE TRAILING OCCURRENCES OF Q ENTIRELY IF Q ALSO
A OCCURS AS THE LEADING ELEMENT. THE LEADING OCCURRENCES
A ARE DELETED WHEN "...-1φ..." IS SPECIFIED.

RESULT: *A*BB*CCC

A NOTE: $L \vee^{-1} \downarrow 1, L$ AND $L \vee 1 \phi L$ [AND THEIR COMPLEMENTS]
A ARE "KERNEL" APL OPERATIONS

DELETING ELEMENTS FROM A VECTOR V

DELETING REDUNDANT OCCURRENCES OF ALL ELEMENTS

$V \leftarrow (1, (1 \downarrow V) \neq -1 \downarrow V) / V$

A REDUNDANT = THE 2ND, 3RD, ETC., CONTIGUOUS OCCURRENCES

EXAMPLE: $V \leftarrow 'AAABBCBBAAABC' /$

RESULT: ABCBABC

A NOTE: THIS SELECTS THE 1ST OCCURRENCES OF ELEMENTS

A IN THE FIELDS OF REDUNDANT ELEMENTS. TO SELECT THE

A LAST OCCURRENCES:

$V \leftarrow (((1 \downarrow V) \neq -1 \downarrow V), 1) / V$

DELETING ELEMENTS FROM A VECTOR V

DELETING LEADING,.TRAILING, AND REDUNDANT OCCURRENCES
OF ELEMENT Q

$V \leftarrow (1 \uparrow L) \downarrow (L * 1 \phi L \leftarrow V = Q) / V$

EXAMPLE: *DELETING BLANKS*

$V \leftarrow$ A BC DEF GHIJ
 $Q \leftarrow$

RESULT: A BC DEF GHIJ

DELETING ELEMENTS FROM A VECTOR V

DELETING THE ELEMENTS WITH INDICES I

$V \leftarrow (\sim(\text{ip } V) \in I) / V$

EXAMPLE: $V \leftarrow 15 \ -37 \ 0 \ 22 \ -3 \ -19 \ 8$
 $I \leftarrow 2 \ 5 \ 6$ $[\square I 0 \leftarrow 1]$

RESULT: 15 0 22 8

A ALTERNATE IMPLEMENTATIONS:

$V \leftarrow (\wedge \neq I \circ . \neq \text{ip } V) / V$

$V \leftarrow (\sim \vee \neq I \circ . = \text{ip } V) / V$

DELETING ELEMENTS FROM A VECTOR V

DELETING A SUBSTRING WITH STARTING INDEX I AND LENGTH L

$V \leftarrow (P \uparrow V), (L + P \leftarrow I - \square IO) \downarrow V$

$\square IO \leftarrow 1 : V \leftarrow (P \uparrow V), (L + P \leftarrow I - 1) \downarrow V$
 $\square IO \leftarrow 0 : V \leftarrow (I \uparrow V), (L + I) \downarrow V$

EXAMPLE: $V \leftarrow 'ABCDEFGHIJKLMNP'$
 $I \leftarrow 8$ $[\square IO \leftarrow 1]$
 $L \leftarrow 4$

RESULT: ABCDEFGLMNOP

A ALTERNATE IMPLEMENTATIONS:

$V \leftarrow (\square IO - I) \phi L \downarrow (I - \square IO) \phi V$

A NOTE: THE ABOVE IMPLEMENTATION WILL DELETE A SUBSTRING
WRAPPED AROUND THE ENDS OF V

$V \leftarrow V[(\downarrow P), ((L + P \leftarrow I - \square IO) - \rho V) \uparrow \rho V]$

$V \leftarrow (\sim(\downarrow \rho V) \in (I - \square IO) + \downarrow L) / V$

A TO DELETE MULTIPLE SUBSTRINGS WITH SAME LENGTH:

$V \leftarrow (\sim(\downarrow \rho V) \in (I - \square IO) \circ . + \downarrow L) / V$

EXAMPLE: $I \leftarrow 1 6 11$ $[\square IO \leftarrow 0]$

RESULT: AFKP

A NOTE: TO DELETE MULTIPLE OCCURRENCES, SEE ALSO THE
TECHNIQUE "REPLACING MULTIPLE OCCURRENCES ..."

DELETING ELEMENTS FROM A VECTOR V

DELETING DUPLICATE OCCURRENCES OF ALL ELEMENTS

$V \leftarrow ((1 \rho V) = V \wr V) / V$

- Ⓐ ELEMENTS OF RESULT OCCUR IN SAME ORDER AS THEIR FIRST OCCURRENCE IN V

EXAMPLE: $V \leftarrow 'TENNESSEE'$

RESULT: TENS

- Ⓐ ALTERNATE IMPLEMENTATION:

$V \leftarrow ((2 \rho \Box I O) \& < \backslash V \circ . = V) / V$ **

- Ⓐ ALTERNATE IMPLEMENTATION, ONLY WHEN V IS NUMERIC

$V \leftarrow (1, (1 + V) \neq -1 + V) / V \leftarrow V[\Delta V]$

- Ⓐ ELEMENTS OF RESULT ARE SORTED IN ASCENDING ORDER

EXAMPLE: $V \leftarrow 4 3 2 1 3 2 1$

RESULT: 1 2 3 4

** ADAPTED FROM (1) THE APL IDIOM LIST

(CONT'D ON NEXT PAGE)

DELETING ELEMENTS FROM A VECTOR V

DELETING DUPLICATE OCCURRENCES OF ALL ELEMENTS (CONTD)

A SPECIAL CASE IMPLEMENTATIONS:

A WHEN V CONTAINS INDICES AND $(\rho V) > \lceil / V$

```
B←((⌈ / V) + ~□IO)ρ 0
B[ V ]←1
Y←B / 1ρ B
```

A ELEMENTS OF RESULT ARE IN ASCENDING ORDER

A CAUTION: THIS IS NOT EFFICIENT IF \lceil / V IS MUCH GREATER THAN ρV

A CAUTION: THE INDICES IN V MUST BE GENERATED IN THE SAME ORIGIN IN WHICH THE CODE IS TO BE EXECUTED

EXAMPLE: $V \leftarrow 5 \ 4 \ 4 \ 3 \ 3 \ 3 \ 2 \ 2 \ 1 \ 4 \ 4 \ 4 \ 3 \ 5 \ 5 \ 2 \ 2 \ 2$

RESULT: $1 \ 2 \ 3 \ 4 \ 5 \quad [\square IO \leftarrow 1]$

A ALTERNATE IMPLEMENTATION:

```
V←(N∈V)/N←1(⌈ / V)+~□IO
```

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