

# Exploring Computer Science Concepts

Via ACSL Competitions

# Number Systems

- Decimal
  - base 10
- Binary
  - base 2
- Octal
  - base 8
- HexaDecimal
  - base 16

# Digits per base

- Decimal
  - Ten digits
  - 0 1 2 3 4 5 6 7 8 9
- Binary
  - Two Digits
  - 0 1
- Octal
  - 8 digits
  - 0 1 2 3 4 5 6 7
- Hexadecimal
  - 16 digits
  - 0 1 2 3 4 5 6 7 8 9 A B C D E F

# Counting in Decimal

- Increment the lowest place value ( right most digit)

- When last digit is reached

- Set the current column to 0

- Increment the column on the left by 1

- Lets count with decimal

- 0 to 10

- 95 to105

- How frequently do we add a new digit ?

Decimal	Decimal
0	95
1	96
2	97
3	98
4	99
5	100
6	101
7	102
8	103
9	104
10	105

# Counting in other bases

- Counting in binary
  - We add a new digit frequently
    - At 2, 4, 8, 16 ... decimal values
- Counting in Octal
  - We add a new digit at every
    - At 8, 64, 128 ...
- Counting in HexaDecimal
  - We add a new digit at every
    - At 16, 256 ... values

Decimal	Binary	Octal	HexaDecimal
0	0	0	1
1	1	1	1
2	10	2	2
3	11	3	3
4	100	4	4
5	101	5	5
6	110	6	6
7	111	7	7
8	1000	10	8
9	1001	11	9
10	1010	12	A
11	1011	13	B
12	1100	14	C
13	1101	15	D
14	1110	16	E
15	1111	17	F
16	10000	20	10

# Place Values

- Decimal
  - We deal in power of 10s
  - $2452 = 2 * 1000 + 4 * 100 + 5 * 10 + 2 * 1$
  - $101 = 1 * 100 + 0 * 10 + 1 * 1$
- Binary
  - We deal in power of 2s
  - $111 = 1 * 4 + 1 * 2 + 1 * 1$
  - $1010 = 1 * 8 + 0 * 4 + 1 * 2 + 0 * 1$

# Place values

## Converting binary → decimal

Decimal	Binary
2452 → $2 \times 10^3 = 2000$ $4 \times 10^2 = 400$ $5 \times 10^1 = 50$ $2 \times 10^0 = 2$ = 2452	111 → $1 \times 2^2 = 1 \times 4 = 4$ $1 \times 2^1 = 1 \times 2 = 2$ $1 \times 2^0 = 1 \times 1 = 1$ = 7
101 → $1 \times 10^2 = 100$ $0 \times 10^1 = 0$ $1 \times 10^0 = 1$ = 101	1010 → $1 \times 2^3 = 1 \times 8 = 8$ $0 \times 2^2 = 0 \times 4 = 0$ $1 \times 2^1 = 0 \times 2 = 2$ $0 \times 2^0 = 0 \times 1 = 0$ = 10
756 →	1000 →

# Converting Binary to Decimal

128	64	32	16	8	4	2	1
<hr/>							

$$1 \ 0 \ 0 \ 1 \ 0 \ 0 \ 1 = 64 + 16 + 1 = 81$$

$$1 \ 0 \ 0 \ 0 \ 0 \ 1 \ 1 \ 1 = 128 + 4 + 2 + 1 = 135$$

$$1 \ 1 \ 1 \ 0 \ 0 \ 0 \ 0 \ 0 = ?$$

# Converting Decimal to Binary

128    64    32    16    8    4    2    1

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$$= \quad 22$$

$$= \quad 33$$

$$= \quad 130$$

# Exercises

- Convert following Decimal numbers to binary
  - $127_{10}$
  - $128_{10}$
  - $129_{10}$
  - $255_{10}$
  - $256_{10}$
- Convert following Binary numbers to Decimal
  - $101101_2$
  - $1110_2$
  - $1111_2$
  - $0110_2$

# Challenge

- How does binary addition and subtraction work ?

# Place values

## Converting octal,hexadecimal → decimal

Octal → Decimal	HexaDecimal → Decimal
<b>777 →</b> $\begin{aligned}7 \times 8^2 &= 7 \times 64 = 448 \\7 \times 8^1 &= 7 \times 8 = 56 \\7 \times 8^0 &= 7 \times 1 = 7 \\&= 511\end{aligned}$	<b>2AB →</b> $\begin{aligned}2 \times 16^2 &= 2 \times 256 = 512 \\A \times 16^1 &= 10 \times 16 = 160 \\B \times 16^0 &= 11 \times 1 = 11 \\&= 683\end{aligned}$
<b>137 →</b> $\begin{aligned}1 \times 8^2 &= 1 \times 64 = 64 \\3 \times 8^1 &= 3 \times 8 = 24 \\7 \times 8^0 &= 7 \times 1 = 7 \\&= 95\end{aligned}$	<b>101 →</b> $\begin{aligned}1 \times 16^2 &= 1 \times 256 = 256 \\0 \times 16^1 &= 0 \times 16 = 0 \\1 \times 16^0 &= 1 \times 1 = 1 \\&= 257\end{aligned}$
<b>756 →</b>	<b>4A3 →</b>

# Converting Decimal to Octal

$$(312)_{10} \rightarrow (?)_8$$

$312 / 8 \rightarrow$  quotient : 39 , Remainder 0

$39 / 8 \rightarrow$  quotient : 4 , Remainder 7

$4 / 8 \rightarrow$  quotient : 0 , Remainder 4

$$(470)_8$$

$$(112)_{10} \rightarrow (?)_8$$

$112 / 8 \rightarrow$  quotient : 14 , Remainder 0

$14 / 8 \rightarrow$  quotient : 1 , Remainder 6

$1 / 8 \rightarrow$  quotient : 0 , Remainder 1

$$(160)_8$$

# Exercises

- Convert following Decimal numbers to Octal
  - $111_{10}$
  - $88_{10}$
  - $511_{10}$
  - $512_{10}$
  - $513_{10}$
- Convert following Octal numbers to Decimal
  - $45_8$
  - $77_8$
  - $100_8$
  - $101_8$

# Converting Decimal to Hexadecimal

$$(312)_{10} \rightarrow (?)_8$$

$312 / 16 \rightarrow$  quotient : 19 , Remainder 8

$19 / 16 \rightarrow$  quotient : 1 , Remainder 3

$1 / 16 \rightarrow$  quotient : 0 , Remainder 1

$$(138)_{16}$$

$$(112)_{10} \rightarrow (?)_8$$

$112 / 16 \rightarrow$  quotient : 7 , Remainder 0

$7 / 16 \rightarrow$  quotient : 0 , Remainder 7

$$(70)_{16}$$

# Hexadecimal → Octal

$(AC)_{16} \rightarrow (1010)_2 \times 16 + (1100)_2 \times 1$  // Replace hexa with binary  
 $\rightarrow (1010\ 1100)_2$  // Convert to binary  
 $\rightarrow (010\ 101\ 100)_2$  // group by 3s , added extra 0s in the front  
 $\rightarrow (254)_8$ // Replace each group by octal value

$(1EF)_{16} \rightarrow (0001)_2 \times 256 + (1110)_2 \times 16 + (1111) \times 1$   
 $\rightarrow (0001\ 1110\ 1111)_2$  // Convert to binary  
 $\rightarrow (000\ 111\ 101\ 111)_2$  // group by 3 , removed 0s in the front  
 $\rightarrow (757)_8$ // Replace each group by octal value

# Octal → Hexadecimal

- $(\text{757})_8 \rightarrow (?)_{16}$
- $(\text{254})_8 \rightarrow (?)_{16}$

# Exercises

- Convert following Decimal numbers to HexaDecimal/Octal
  - $255_{10}$
  - $256_{10}$
  - $257_{10}$
- Convert following HexaDecimal numbers to Decimal, Octal
  - $99_{16}$
  - $100_{16}$
  - $101_{16}$

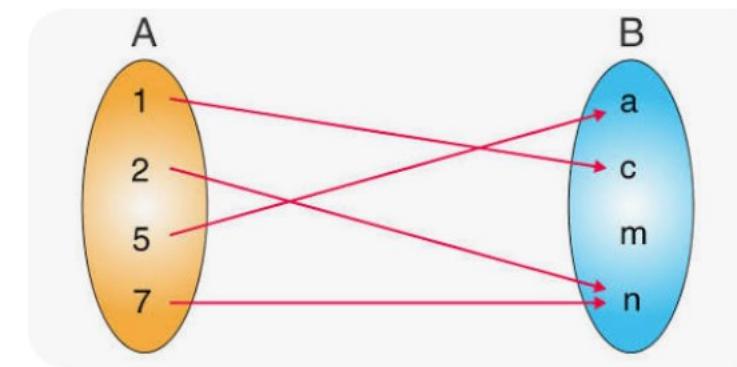
# Recursion : programming

- Create factorial
  - $5! = 5 \times 4 \times 3 \times 2 \times 1 = 120$
  - $2! = 2$
- Provide sum of Fibonacci numbers using recursion
  - fibonacci(13)
    - $0 + 1 + 1 + 2 + 3 + 5 + 8 + 13 = 33$
  - fibonacci(3)
    - $0 + 1 + 1 + 2 + 3 = 7$

# Relations

- A **relation** : connection/mapping between elements of two or more sets, Some characteristics ...

- It is a **mapping** as shown in figure
- Can be written as **Ordered pairs**
  - $\{(1,c), (2,n),(5,a),(7,n)\}$
- Not always unique
  - E.g.  $y^2 = 4$  has multiple solutions (how many?)



- Examples
  - Numerical relationship :  $4+3 = 7$
  - Equation :  $y = 2x+3$
  - Geometry : two congruent triangles
  - Set theory : A is a subset of B

# Functions , mathematical kind

- A **relation** that gives exactly **one unique output for each input**

$x \rightarrow$    $y$  :this is a function as you always get one answer

$x \rightarrow$    $a$   $b$   $c$  :Not a function as you get multiple answers

- Representation
  - $f(x) = 2x+1$  :this is a function
  - $g(x) = \pm 3x$  :this is **not** a function , why?
- Follow up reading (optional): pg 11-13 : [functions](#)

# Evaluating functions

- Solving
  - Substitute variables with numerals
  - Evaluate
    - Follow PEMDAS/BODMAS
- Solve for  $x = 0, 1, 2, 3$ 
  - $f(x) = 3x + 1$
  - $g(x) = 2x^2 + 3$
  - $h(x) = x^2 + 2x + 1$

# Recursive Functions

- Functions calling themselves

<b>Fibonacci numbers</b>	$fib: \mathbb{N} \rightarrow \mathbb{N}$ $fib(n) = \begin{cases} 0, & \text{if } n = 0 \\ 1, & \text{if } n = 1 \\ fib(n - 1) + fib(n - 2), & \text{if } n \geq 2. \end{cases}$
<b>Factorial</b>	$\mathbf{fact(n) = n * fact(n-1)}$ $\{\text{given, } fact(1) = fact(0) = 1\}$
<b>Lucas numbers</b> <i>(same rule as Fibonacci but with different starting values)</i>	$\mathbf{l(n) = l(n-1) + l(n-2)}$ $\{\text{given, } l(0) = 2, l(1) = 1\}$

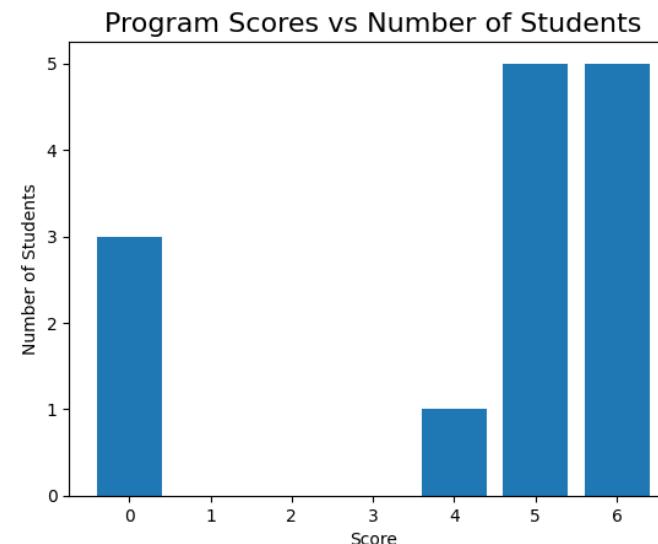
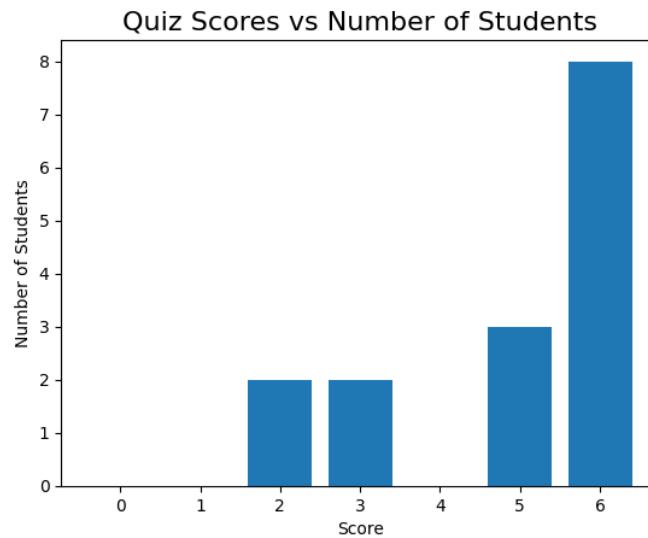
- Evaluate for ‘n’ = 2 , 4, 5, 6
- Follow up reading (optional): [nested functions visualized](#)

# Programming, , Test #1

- Need to know
  - Data types
  - Conditionals : If/else
  - Loops : for
  - Arrays : 2 dimensional
- Practice
  - Arrays- DS (Hackerrank)
    - Do the 4 problems marked “easy”
    - Optional :“hard”, “medium” one are for extra challenge

# Test 1, observations

- Great participation, nearly everyone attempted!
- Overall students did better in quiz
  - 8x full marks in quiz vs 5x full marks in programming
- **4 students got a zero in programming ( with 1 not attempted)**



# Test 2 , analysis

- The quizzes
  - seem to be easier for students to master
  - Success cause everyone attempted, next we figure out how to raise scores there
    - Suggestions ?
- Programming
  - It was amazing attempt
  - The codes generally worked
  - But 4/15 students had zeroes.
  - Suggestions ?
- Goal :We need raise scores for everyone and move some in attempted stage
  - Note
    - Compete with yourself , Do better than your last attempt
    - Ask for help
      - on what you don't know, to learn it.
      - And even on what you know , i.e. to master it

# Topics for Test 2

- Mathematical expressions
  - Representations ( infix, prefix, postfix)
  - Evaluation of expression
- Discrete Mathematics
  - Logical Operators (AND , OR , NOT, SHIFT,...)
  - Boolean logic
- Programming
  - char, string ,arrays
  - Loops
  - Conditionals
    - If/else
    - switch/case

# Infix expressions

- Encounter them in grade maths. e.g.
  - $(11+14)/(9 - 3) + 2$
  - $3+7 / (4 * 5 - 6)$
  - $- 2 + 8 / 2$
- Can also be written using variables
  - $(a + b) / (c - d ) + e$
  - $x + y / (g * h - k)$
- Evaluated using
  - PEMDAS / BODMAS

# Expression : anatomy

- Expression is made of
  - Operators ( + , - , \* , /)
  - Operands (numbers, variables)
- Unary operators :  $- a$ 
  - <operator> <operand>
- Binary operators (infix) :  $a + b$ 
  - < operand> <operator> <operand>

# Prefix/Postfix expressions

- Benefits
  - Remove ambiguity( i.e. can forget PEMDAS, BODMAS)
  - Computer friendly
  - Works with both unary/binary
  - Faster evaluation
- Expression styles
  - Infix : operator in **middle** of operands
    - $(5+6)*3$
    - <**operand**> <*operator*> <**operand**>
  - Prefix : operator **before** operands
    - \* + 5 6 3
    - <*operator*> <**operand**> <**operand**>
  - Postfix : operator **after** operands
    - 5 6 + 3 \*
    - <**operand**> <**operand**> <*operator*>

# Evaluating expression, *but first Stacks and Queues*

- What is a **Stack** ?
  - This is a sequential structure of **items**
  - That are **pushed at one end**
  - **Pulled via the same end**
  - **LIFO** : Last in First Out
  - Examples
    - Stack of plates
    - Your turned in paper assignments
- What is a **Queue**?
  - Another sequential structure of **items**
  - that are **pushed at one end**
  - **Pulled via the opposite end**
  - **FIFO** : First In First Out
  - Examples
    - Queue for buying tickets
    - Traffic in one way single lane

# Evaluating prefix expression

- Infix :  $(5+6)*3$ 
  - \* + 5 6 3
  - - + 2 \* 3 4 / 16 ^ 2 3
- Algorithm (harder way)
  - Scan from right to left
  - Anytime you find an operator
    - Evaluate the operation using the previous 2 operands
    - Replace the *operator* <ôřêšâñđ> with *sêşuł'tj* in the expression
  - Repeat the steps till only 1 operand is left

# Evaluating postfix expression

- Evaluate
  - $2\ 3\ 1\ *\ +\ 9\ -$
  - $5\ 3\ +\ 6\ 2\ /\ *\ 3\ 5\ *\ +$
- *Algorithm to evaluate (use stack)*
  1. Push the operands in a stack
  2. When you encounter a operator
    - Pop 2 operands
    - Perform the operation on operands
    - Push the result in stack
  - Repeat from 1 until expression is parsed
  - The last item in stack is the answer
    - There would be only 1 item left when done correctly
- \* prefix expr can also be evaluated in this way (*just in reverse*)

# Evaluate

- Prefix
  - $- * 5 + - 4 2 2 / 6 3$
  - $- * + 3 5 7 + / 4 2 1$
  - $- + 10 * 2 3 + 4 / 5 5$
- Postfix
  - $1 2 + 3 4 + * 5 6 - / 7 +$
  - $8 2 / 3 4 + * 5 1 + 2 / -$
  - $9 8 4 2 1 ^ * / - 3 +$

# Answers

- Prefix
  - $- * 5 + - 4 2 2 / 6 3$ 
    - Ans : 18
  - $- * + 3 5 7 + / 4 2 1$ 
    - Ans : 53
  - $- + 10 * 2 3 + 4 / 5 5$ 
    - Ans : 11
- Postfix
  - $1 2 + 3 4 + * 5 6 - / 7 +$ 
    - Ans : -14
  - $8 2 / 3 4 + * 5 1 + 2 / -$ 
    - Ans : 25
  - $9 8 4 2 1 ^ * / - 3 +$ 
    - Ans : 11

# Practice: Programming

- Write a function that takes a string and checks if it is a palindrome
  - Returns true if palindrome is found else false
  - Hints: string indexing, loops, if , comparing characters
- Count the number of vowels, consonants in a sentence.
  - Vowels : a,e,i,o,u
  - Consonant : everything else other than vowels
  - Ignore : spaces (' ') comma(,) dash(-),semicolon(;),colon( :)
- Find the most frequent word in a sentence
  - If more than 1 word has same frequency return the lexicographically smaller one.

# Review Evaluating Prefix/Postfix

- From last week
  - Operator
  - Operand
  - Stack
  - Queue
- Evaluating Prefix/Postfix
  - <3 questions each>

# Precedence and associativity

- Precedence ( highest priority first)
  - ()
  - ^
  - / \*
  - - +
- Associativity
  - Right to left : ^
  - Left to right : + , - , \* , /
- Notes
  - () not categorized as associative, they represent grouping mechanism

# Precedence and associativity

- Example
  - $10 + 20 / 2 * 3 - 5$ 
    - $\rightarrow 10 + ((20 / 2) * 3) - 5$  // added parenthesis for denoting precedence
    - $\rightarrow 10 + (10 * 3) - 5$  // interior most precedence first
    - $\rightarrow 10 + 30 - 5$
    - $\rightarrow 35$

# Precedence and associativity (lets evaluate)

- $2 + 3 * 4 ^2$
- $2 ^3 ^2$
- $100 / 2 * 5 ^2 ^1$

# Precedence and associativity (answers)

- $2 + 3 * 4 ^2$ 
  - $\rightarrow 2 + 3 * 16$
  - $\rightarrow 2 + 48$
  - $\rightarrow 50$
- $2 ^3 ^2$ 
  - $\rightarrow 2 ^9 //$  ^ is evaluated from right to left , so  $3 ^2$  goes first
  - $\rightarrow 512$
  - ~~Not 64~~
- $100 / 2 * 5 ^2 ^1$ 
  - $\rightarrow 100 / 2 * 25 //$  Again  $2 ^1$  goes first
  - $\rightarrow 50 \times 25$
  - $\rightarrow 1250$

# Convert to Prefix/Postfix (examples)

- $B * C$ 
  - Prefix : **\* B C**
  - Postfix : **B C \***
- $A + B * C$ 
  - Prefix : **+ A \* B C**
  - Postfix : **A B C \* +**
- $(5 + 6) * 3$ 
  - Prefix : **\* + 5 6 3**
  - Postfix : **5 6 + 3 \***

# Convert to Postfix

- How to convert!
  - Convert the highest precedence/priority first
  - ( do paranthesize for mental ease)
- $(a + b) / (c - d) + e$
- $x + y / (g * h - k)$

# Convert to Postfix

- How to convert!
  - Convert the highest priority first
  - ( and paranthesize for mental ease)
- $(a + b) / (c - d) + e$ 
  - Prefix : **+ / + a b - c d e**
  - Postfix : **a b + c d - / e +**
- $x + y / (g * h - k)$ 
  - Prefix : **+ x / y - \* g h k**
  - Postfix : **x y g h \* k - / +**

# Convert to Prefix and Postfix

- $a + b - c * d + e ^ f$
- $(a + b) * c - (d - e) * (f + g)$
- $((a + b) * (c + d) / (e - f)) + g$
- $a * (b + c) / (d - e)$
- $a - b / (c * d ^ e)$
- $(a + b) * (c + d) - e$

# Convert to Prefix and Postfix (answers)

Infix	Prefix	Postfix
$a + b - c * d + e ^ f$	$+ - + a b * c d ^ e f$	$a b + c d * - e f ^ +$
$(a + b) * c - (d - e) * (f + g)$	$- * + a b c * - d e + f g$	$a b + c * d e - f g + * -$
$((a + b) * (c + d) / (e - f)) + g$	$+ / * + a b + c d - e f g$	$a b + c d + * e f - / g +$
$a * (b + c) / (d - e)$	$/ * a + b c - d e$	$a b c + * d e - /$
$a - b / (c * d ^ e)$	$- a / b * c ^ d e$	$a b c d e ^ * / -$
$(a + b) * (c + d) - e$	$- * + a b + c d e$	$a b + c d + * e -$

# Logical operators (for bits/bytes)

- Bitwise
  - NOT, AND, XOR , OR
- Shift
  - Linear : LSHIFT, RSHIFT,
  - Circular : RCIRC, LCIRC
- Precedence
  - NOT,
  - SHIFT, CIRC,
  - AND ,
  - XOR,
  - OR

# Truth Tables

X	NOT X
0	1
1	0

X	Y	X AND Y	X OR Y	X XOR Y
0	0	0	0	0
0	1	0	1	1
1	0	0	1	1
1	1	1	1	0

# Truth Tables

- Linear shift , add 0s as padding ( either left or right)
  - Shifting by word size (or more) would result in all 0s
- Circular shift just rolls over the bits ( as per direction)
  - Shifting by the number of word size , same bit sequence would be produced

X	(LSHIFT-2 X)	(RSHIFT-3 X)	(LCIRC-3 X)	(RCIRC-1 X)
01101	10100	00001	01011	10110
10	00	00	01	01
1110	1000	0001	0111	0111
1011011	1101100	0001011	1011101	1101101

# Operations (evaluate)

- 0110 AND 1011
- 1100 OR 0101
- 1010 XOR 1111
- 1010 AND 1100 OR 0001
- 0011 OR 1010 AND 0110
- (1100 XOR 1010) AND 0110

# Operations (evaluate)

- 0110 AND 1011
- 1100 OR 0101
- 1010 XOR 1111
- 1010 AND 1100 OR 0001
- 0011 OR 1010 AND 0110
- (1100 XOR 1010) AND 0110

# Operations : Shift (evaluate)

1. (LSHIFT-1 10101) AND (RSHIFT-2 11010)
2. (RCIRC-2 01111) OR (LSHIFT-3 10010)
3. (RSHIFT-1 11100) XOR (LCIRC-2 01011)
4. (LSHIFT-2 00110) OR (RCIRC-1 10101) AND (RSHIFT-3 11101)
5. (LCIRC-3 11001) AND (RSHIFT-2 10110)
6. (RCIRC-4 10011) OR (LSHIFT-1 01101)
7. (RSHIFT-3 11110) AND (LCIRC-1 00111) OR (LSHIFT-2 01010)
8. (LSHIFT-2 01101) OR (RCIRC-3 10110) AND (RSHIFT-1 11011)

# Answers 1..3

1. (LSHIFT-1 10101) AND (RSHIFT-2 11010)
  - → 01010 AND 00110
  - → **00010**
2. (RCIRC-2 01111) OR (LSHIFT-3 10010)
  1. → 11011 OR 10000
  2. → **11011**
3. (RSHIFT-1 11100) XOR (LCIRC-2 01011)
  1. → 01110 XOR 01101
  2. → **00011**

# Answers 4..6

4. (LSHIFT-2 00110) OR (RCIRC-1 10101) AND (RSHIFT-3 11101)
  - 11000 OR 11010 AND 00011 //*parenthesis evaluated first*
  - 11000 OR 00010 //*And has higher precedence so evaluated first*
  - **11010**
5. (LCIRC-3 11001) AND (RSHIFT-2 10110)
  - 01110 AND (RSHIFT-2 10110)
  - 01110 AND 00101
  - **00100**
6. (RCIRC-4 10011) OR (LSHIFT-1 01101)
  - 00111 OR 11010
  - **11111**

# Answers 7..8

7. (RSHIFT-3 11110) AND (LCIRC-1 00111) OR (LSHIFT-2 01010)
  - 00011 AND 01110 OR (01000)
  - 00010 OR 01000
  - **01010**
8. (LSHIFT-2 01101) OR (RCIRC-3 10110) AND (RSHIFT-1 11011)
  - 11010 OR 11010 AND 01101
  - 11010 OR 01000
  - **11010**