Young Gates Coding League (YGCL)

Young Gates

KIDS ONLINE STEM CLASSES

SCIENCE • TECHNOLOGY • ENGNEERING • MATHEMATICS

Index

Explorer Division

Focuses on foundational concepts like algorithms, pattern recognition, and introductory logic

Chapter 1: The World of Computer Number Systems

Dive into the fundamental building blocks of the digital age!

This contest will introduce participants to various computer number systems, their applications, and techniques for conversions.

What Student will learn from Chapter 1

- Convert numbers between different bases (e.g., binary to decimal, hexadecimal to octal).

- Perform addition, subtraction, multiplication, and division in binary, octal, and hexadecimal systems.

- Develop logic-building and critical thinking skills by solving real-world problems like binary range calculations and bitwise operations.

Topics Covered:

1. Binary System (Base-2):
   - Understanding binary digits (bits).
   - Applications in computers and digital systems.
2. Octal System (Base-8):
   - Basics of octal representation.
   - Converting between octal and other number systems.
3. Decimal System (Base-10):
   - Revisiting everyday numbers.
   - Relationship between decimal and binary.
4. Hexadecimal System (Base-16):
   - Introduction to hexadecimal representation.
   - Applications in memory addressing and color codes.
5. Conversions:
   - Binary ⇔ Decimal
   - Binary ⇔ Octal
   - Binary ⇔ Hexadecimal

Sample- Computer Number Systems

Question 1:
What is the decimal (base 10) equivalent of the octal number 2478?
Solution:
Convert each digit of the octal number to decimal:
2478=7×80+4×81+2×82247_8 = 7 \times 8^0 + 4 \times 8^1 + 2 \times 8^2
=7×1+4×8+2×64= 7 \times 1 + 4 \times 8 + 2 \times 64
=7+32+128=167= 7 + 32 + 128 = 167
Answer: 167 or 16710167_{10}
Question 2:
Which of the following numbers is the largest?

- 5738
- 3F16
- 29910

Solution:
Convert all numbers to base 10:

1. 5738=3×82+7×81+3×80=3×64+7×8+3×1=192+56+3=251573_8 = 3 \times 8^2 + 7 \times 8^1 + 3 \times 8^0 = 3 \times 64 + 7 \times 8 + 3 \times 1 = 192 + 56 + 3 = 251
2. 3F16=3×161+15×160=48+15=633F_{16} = 3 \times 16^1 + 15 \times 16^0 = 48 + 15 = 63
3. 29910=299299_{10} = 299

The largest number is 29910299_{10}.
Answer: 299

Sample- Computer Number Systems

Question 3:

Evaluate:

4378+5638−2048437_8 + 563_8 - 204_8

Express the answer in octal.

Solution:

Convert all numbers to base 10 for calculation:

- 4378=4×82+3×81+7×80=256+24+7=28710437_8 = 4 \times 8^2 + 3 \times 8^1 + 7 \times 8^0 = 256 + 24 + 7 = 287_{10}
- 5638=5×82+6×81+3×80=320+48+3=37110563_8 = 5 \times 8^2 + 6 \times 8^1 + 3 \times 8^0 = 320 + 48 + 3 = 371_{10}
- 2048=2×82+0×81+4×80=128+4=13210204_8 = 2 \times 8^2 + 0 \times 8^1 + 4 \times 8^0 = 128 + 4 = 132_{10}

Perform the calculation in base 10:

287+371−132=526287 + 371 - 132 = 526

Convert 52610526_{10} back to octal:

526÷8=65 R 6526 \div 8 = 65 \text{ R } 6

65÷8=8 R 165 \div 8 = 8 \text{ R } 1

8÷8=1 R 08 \div 8 = 1 \text{ R } 0

So, 52610=10168526_{10} = 1016_{8}.

Answer: 101681016_{8}

Sample- Computer Number Systems

Question 4:
How many binary numbers between 2020 and 4040 (inclusive) in base 10 have more 11's than 00's?
Solution:
Convert the decimal range 2020 to 4040 into binary:

- 20=10100,21=10101,22=10110,23=10111,…,40=10100020 = 10100, 21 = 10101, 22 = 10110, 23 = 10111, \dots, 40 = 101000

Count binary numbers with more 11's than 00's:

- 21(10101),23(10111),27(11011),29(11101),31(11111),35(100011),39(100111)21 (10101), 23 (10111), 27 (11011), 29 (11101), 31 (11111), 35 (100011), 39 (100111).

There are 77 such numbers.
Answer: 7
Question 5: A color is represented by the hexadecimal number B35E2A16.
What is the sum of the decimal values of the red and the blue components?
Solution:
Split the RGB components:

- Red: B316B3_{16}
- Blue: 2A162A_{16}

Convert each to decimal:

- B316=11×16+3=176+3=179B3_{16} = 11 \times 16 + 3 = 176 + 3 = 179
- 2A16=2×16+10=32+10=422A_{16} = 2 \times 16 + 10 = 32 + 10 = 42

Sum: 179+42=221179 + 42 = 221.
Answer: 221

Sample- Computer Number Systems

Question 5:

What is the binary (base 2) equivalent of the hexadecimal number 3F16?

Solution:

Convert each hexadecimal digit to binary:

- 316=001123_{16} = 0011_2
- F16=11112F_{16} = 1111_2

Combine the results: 3F16=0011111123F_{16} = 00111111_2.

Answer: 00111111200111111_2 or 1111112111111_2

Question 6:

Which of the following is the smallest number?

- 5478
- A916
- 12510

Solution:

Convert all numbers to base 10 for comparison:

1. 5478=5×82+4×81+7×80=320+32+7=359547_8 = 5 \times 8^2 + 4 \times 8^1 + 7 \times 8^0 = 320 + 32 + 7 = 359
2. A916=10×161+9×160=160+9=169A9_{16} = 10 \times 16^1 + 9 \times 16^0 = 160 + 9 = 169
3. 12510=125125_{10} = 125

The smallest number is 12510125_{10}.

Answer: 125

Sample- Computer Number Systems

Question 7:

Evaluate:

1438−678+21381438 - 678 + 2138

Express the answer in base 8.

Solution:

Convert all numbers to base 10:

- 1438=1×82+4×81+3×80=64+32+3=9910143_8 = 1 \times 8^2 + 4 \times 8^1 + 3 \times 8^0 = 64 + 32 + 3 = 99_{10}
- 678=6×81+7×80=48+7=551067_8 = 6 \times 8^1 + 7 \times 8^0 = 48 + 7 = 55_{10}
- 2138=2×82+1×81+3×80=128+8+3=13910213_8 = 2 \times 8^2 + 1 \times 8^1 + 3 \times 8^0 = 128 + 8 + 3 = 139_{10}

Perform the calculation in base 10:

99−55+139=18399 - 55 + 139 = 183

Convert 18310183_{10} to base 8:

183÷8=22 R 7183 \div 8 = 22 \text{ R } 7

22÷8=2 R 622 \div 8 = 2 \text{ R } 6

So, 18310=2678183_{10} = 267_{8}.

Answer: 2678267_{8}

Sample- Computer Number Systems

Question 8:

How many hexadecimal numbers between 20 and 40 in decimal contain at least one letter (A-F)?

Solution:

Convert the decimal range 2020 to 4040 into hexadecimal:

- 2010=1416,2110=1516,…,4010=281620_{10} = 14_{16}, 21_{10} = 15_{16}, \dots, 40_{10} = 28_{16}.

Check which numbers include A–FA-F:

- 1A,1B,1C,1D,1E,1F,2A,2B,2C,2D,2E,2F1A, 1B, 1C, 1D, 1E, 1F, 2A, 2B, 2C, 2D, 2E, 2F.

There are 1212 such numbers.

Answer: 12

Question 9:

A hexadecimal color code is represented as 6C3B8F16.

What is the decimal sum of the green and blue components?

Solution:

Split the RGB components:

- Green: 3B163B_{16}
- Blue: 8F168F_{16}

Convert each to decimal:

- 3B16=3×16+11=48+11=593B_{16} = 3 \times 16 + 11 = 48 + 11 = 59
- 8F16=8×16+15=128+15=1438F_{16} = 8 \times 16 + 15 = 128 + 15 = 143

Sum: 59+143=20259 + 143 = 202.

Answer: 202

Chapter 2: Prefix/Infix/Postfix Notation

This contest focuses on the evaluation and transformation of expressions in different notations used in computational operations: Prefix, Infix, and Postfix.

Students will demonstrate their understanding of these notations, their relationships, and how to evaluate or convert between them.

What Student will learn from Chapter 2

- How to distinguish between Prefix, Infix, and Postfix notations.
-
- Methods to convert between notations.
-
- Application of notations in computer programming and stack-based calculations.
-
- Enhanced problem-solving skills through real-world computational examples.

Topics Covered:

1. **Introduction to Expression Notations**
   - Prefix (Polish) Notation
   - Infix Notation
   - Postfix (Reverse Polish) Notation
2. **Conversion Techniques:**
   - Infix to Postfix Conversion
   - Infix to Prefix Conversion
   - Prefix to Infix Conversion
   - Postfix to Infix Conversion
3. **Evaluation of Expressions:**
   - Evaluating Prefix Expressions
   - Evaluating Postfix Expressions
   - Using Operator Precedence and Associativity
4. **Application in Computing:**
   - Usage of Notations in Stack-Based Calculations
   - Simplifying Complex Expressions in Programming

Sample- Prefix/Infix/Postfix Notation

Sample Questions Based on Prefix/Infix/Postfix Notation

Question 1: Evaluate Prefix Expression

Evaluate the following prefix expression:

- * 8 4 + / 16 2 * 6 3

Solution:

Step-by-step evaluation:

1. Start with / 16 2 = 8.
2. + / 16 2 * 6 3 = 8 + (6 * 3) = 8 + 18 = 26.
3. * 8 4 = 32.
4. - * 8 4 + / 16 2 * 6 3 = 32 - 26 = 6.

Answer: 6

Question 2: Evaluate Postfix Expression

Evaluate the following postfix expression:

5 4 2 * + 10 5 / -

Solution:

Step-by-step evaluation:

1. 4 2 * = 8.
2. 5 + 8 = 13.
3. 10 5 / = 2.
4. 13 - 2 = 11.

Question 3: Translate Infix to Prefix

Question 3: Translate Infix to Prefix
Translate the following infix expression to prefix:
(5 + 7) * (6 - 4) / 2

Solution:

1. Start with the innermost operations:
   - (5 + 7) = + 5 7.
   - (6 - 4) = - 6 4.
2. Combine operations:
   - Multiply: * + 5 7 - 6 4.
   - Divide: / * + 5 7 - 6 4 2.

Answer: / * + 5 7 - 6 4 2

Question 4: Translate Infix to Postfix
Translate the following infix expression to postfix:
5 + (3 * 4) - (6 / 2)
Solution:

- Start with the innermost operations:
  - 3 * 4 = 3 4 *.
  - 6 / 2 = 6 2 /.
- Combine operations:
  - Add: 5 + 3 4 * = 5 3 4 * +.
  - Subtract: 5 3 4 * + 6 2 / -.

Answer: a) 5 3 4 * + 6 2 / -

Question 5: Translate Prefix to Postfix

Translate the following prefix expression to postfix:

- * / + 8 6 4 + 5 3 7

Solution:

- Start with innermost operations:
  - + 8 6 = 8 6 +.
  - / + 8 6 4 = 8 6 + 4 /.
  - + 5 3 = 5 3 +.
- Combine operations:
  - Multiply: * / + 8 6 4 + 5 3 = 8 6 + 4 / 5 3 + *.
  - Subtract: - * / + 8 6 4 + 5 3 7 = 8 6 + 4 / 5 3 + * 7 -.

Answer: a) 8 6 + 4 / 5 3 + * 7 -

Question 6: **Evaluate Prefix Expression**

Evaluate the following prefix expression:

+ * 3 5 - 10 / 20 4

Solution:

Step-by-step evaluation:

1. / 20 4 = 5.
2. - 10 / 20 4 = 10 - 5 = 5.
3. * 3 5 = 15.
4. + * 3 5 - 10 / 20 4 = 15 + 5 = 20.

Answer: **23**

Question 7: Evaluate Postfix Expression

Evaluate the following postfix expression:

8 4 / 3 5 * + 2 -

Solution:

Step-by-step evaluation:

- 8 4 / = 2.
- 3 5 * = 15.
- 2 + 15 = 17.
- 17 - 2 = 15.

Answer: 15

Question 8: Translate Infix to Prefix

Translate the following infix expression to prefix:

(8 - 4) / (5 + 2 * 3)

Solution:

- Start with the innermost operations:
  - (8 - 4) = - 8 4.
  - 2 * 3 = * 2 3.
  - (5 + 2 * 3) = + 5 * 2 3.
- Combine:
  - - 8 4 / + 5 * 2 3 = / - 8 4 + 5 * 2 3.

Answer: / - 8 4 + 5 * 2 3

Question 9: Translate Infix to Postfix
Translate the following infix expression to postfix:
(6 / 3 + 2) * (4 - 5)
Solution:

- Start with the innermost operations:
  - 6 / 3 = 6 3 /.
  - 6 / 3 + 2 = 6 3 / 2 +.
  - (4 - 5) = 4 5 -.
- Combine:
  - 6 3 / 2 + * 4 5 -.

Answer: 6 3 / 2 + 4 5 - *

Question 10: Translate Prefix to Postfix
Translate the following prefix expression to postfix:
+ * 7 - 9 3 / 8 4
Solution:

- Start with innermost operations:
  - - 9 3 = 9 3 -.
  - * 7 - 9 3 = 7 9 3 - *.
  - / 8 4 = 8 4 /.
  - + * 7 - 9 3 / 8 4 = 7 9 3 - * 8 4 / +.

Answer: 7 9 3 - * 8 4 / +

Chapter 3: Boolean Algebra

Boolean Algebra is a branch of algebra that deals with binary variables and logical operations. It is named after George Boole, who introduced this mathematical framework.

Boolean Algebra forms the foundation of digital logic used in computers, programming, and electronic circuit design.

What Student will learn from Contest 3

- Logical Decision-Making:
  - Understand how to make decisions using fundamental logical operators like AND, OR, and NOT.
- Truth Tables:
  - Learn to construct and interpret truth tables to evaluate the outcomes of Boolean expressions based on TRUE and FALSE values.
- Simplification of Expressions:
  - Apply basic Boolean rules to simplify logical expressions into forms that are easier to evaluate and implement.
- Algebraic Representation:
  - Use algebraic notations to represent both complex and simplified Boolean or logical expressions systematically.

Topics Covered:

1. **Basic Logical Operators:**
   - AND (·), OR (+), NOT (¬).
2. **Truth Tables:**
   - Constructing and interpreting truth tables for logical expressions.
3. **Simplification of Boolean Expressions:**
   - Using Boolean identities and laws (e.g., Associative, Commutative, Distributive, and De Morgan's Laws) to simplify expressions.
4. **Logical Decision Making:**
   - Applying logical expressions to evaluate outcomes based on truth values (TRUE or FALSE).
5. **Representation of Complex Logical Statements:**
   - Converting between logical expressions and their algebraic or symbolic forms.

Sample- Boolean Algebra

Evaluate the following expression as either TRUE or FALSE:

$$\text{NOT}(3+5<7)\ \text{OR}\ (4/2\geq 2\ \text{AND}\ 7\times 3>25).$$

Solution:

1. Evaluate $3+5<7$:

   $3+5=8$, and $8<7$ is **FALSE**.

   $\text{NOT (FALSE)} = \text{TRUE}.$

2. Evaluate $4/2\geq 2$:

   $4/2=2$, and $2\geq 2$ is **TRUE**.

3. Evaluate $7\times 3>25$:

   $7\times 3=21$, and $21>25$ is **FALSE**.

4. Combine $4/2\geq 2\ \text{AND}\ 7\times 3>25$:

   $\text{TRUE AND FALSE} = \text{FALSE}.$

5. Combine results:

   $\text{TRUE OR FALSE} = \text{TRUE}.$

Sample- Boolean Algebra

Question 2:

How many ordered pairs make the following statement FALSE?

$$\text{NOT}(A \text{ OR } B) \text{ AND } B \text{ AND NOT} A.$$

Solution:

1. Truth table for the expression:

A	B	A OR B	NOT(A OR B)	NOT A	B AND NOT A	Final Expression
0	0	0	1	1	0	0
0	1	1	0	1	1	0
1	0	1	0	0	0	0
1	1	1	0	0	0	0

2. The final expression is FALSE for all 4 pairs.

Answer: 4 pairs.

Sample- Boolean Algebra

Question 2:

How many ordered pairs make the following statement FALSE?

$$\text{NOT}(A \text{ OR } B) \text{ AND } B \text{ AND NOT } A.$$

Solution:

1. Truth table for the expression:

A	B	A OR B	NOT(A OR B)	NOT A	B AND NOT A	Final Expression
0	0	0	1	1	0	0
0	1	1	0	1	1	0
1	0	1	0	0	0	0
1	1	1	0	0	0	0

2. The final expression is FALSE for all 4 pairs.

Answer: 4 pairs.

Sample- Boolean Algebra

Question 3:

Simplify the Boolean expression:

$$\sim (A+B)+\sim (A+\sim B).$$

Solution:

1. Apply De Morgan's Laws:

$$\sim (A+B) =\sim A\cdot \sim B, \quad \sim (A+\sim B) =\sim A\cdot B.$$

2. Combine:

$$\sim A\cdot \sim B+\sim A\cdot B =\sim A(\sim B+B).$$

3. Simplify:

$$\sim A(1) =\sim A.$$

Answer: $\sim A$.

Sample- Boolean Algebra

Question 4:

Simplify the Boolean expression to remove all AND operations:

$$\sim A + B \cdot \sim A + \sim B \cdot A + \sim B.$$

Solution:

1. Factorize terms:

$$\sim A(1 + B) + \sim B(A + 1).$$

2. Simplify constants:

$$\sim A \cdot 1 + \sim B \cdot 1 = \sim A + \sim B.$$

Answer: $\sim A + \sim B.$

Question 5:

Construct a truth table for the following expression:

$$\sim A + (B \cdot \sim C).$$

Solution:

A	B	C	$\sim A$	$\sim C$	$B \cdot \sim C$	$\sim A + (B \cdot \sim C)$
0	0	0	1	1	0	1
0	0	1	1	0	0	1
0	1	0	1	1	1	1
0	1	1	1	0	0	1
1	0	0	0	1	0	0
1	0	1	0	0	0	0
1	1	0	0	1	1	1
1	1	1	0	0	0	0

Answer: The truth table is as above.

Chapter 4: Graph Theory

Assess students' understanding of fundamental graph theory concepts, including graph representations, traversal algorithms, and basic graph properties.

What Student will learn from Contest 4

Representation of Real-Life Problems:
Students will learn how graphs can model real-life problems like social networks, transportation systems, and communication networks.

Understanding Vertices and Edges:
Students will gain a clear understanding of vertices (nodes) and edges (connections) and how they are used to represent relationships and structures in graphs.

Drawing Graphs:
Students will practice drawing graphs based on given data and interpreting vertices and edges from pre-drawn graphs.

Graph Representation Techniques:
Learn how to represent graphs using adjacency lists and adjacency matrices.

Topics Covered:

1. **Basic Definitions:** Vertices, edges, adjacency, degree of a vertex, and types of graphs (directed, undirected, weighted, unweighted).
2. **Graph Representation:** Adjacency matrix, adjacency list.
3. **Traversal Techniques:** Breadth-First Search (BFS), Depth-First Search (DFS).
4. **Applications of Graphs:** Real-world problem modeling, network analysis.
5. **Types of Graphs:** Cyclic, acyclic, connected, disconnected.
6. **Components of Graphs:** Connected components, isolated vertices.

Sample- Graph Theory

1. Identify Edges from a Description

Amy shakes hands with Dave and Eli. Eli shakes hands with Amy and Ben. Ben shakes hands with Eli, Carol, and Dave. Dave shakes hands with Amy, Ben, and Carol. Carol shakes hands with Ben and Dave.

Question: List all the edges represented using the first letter of each person's name. Do not include duplicates.

Solution:

Edges:

AD, AE (Amy shakes hands with Dave and Eli)

EB, EA (Eli shakes hands with Ben and Amy)

BE, BC, BD (Ben shakes hands with Eli, Carol, and Dave)

DA, DB, DC (Dave shakes hands with Amy, Ben, and Carol)

CB, CD (Carol shakes hands with Ben and Dave)

Answer: AD, AE, EB, BC, BD, DC

2. Completing a Graph

A graph has vertices A, B, C, D, and E. It currently has edges AB, AC, BD, and CE.

Question: Identify the set of edges needed to make this a complete graph. List them in alphabetical order.

Solution:

- A complete graph has an edge between every pair of vertices.
- Total edges for 5 vertices: $5 \times 4/2 = 10$
- Current edges: AB, AC, BD, CE
- Missing edges: AD, AE, BC, BE, CD, DE

Answer: AD, AE, BC, BE, CD, DE

3. Counting Hamiltonian Circuits

A graph has vertices Q, R, S, T, and P. You are delivering pizza starting at Q, visiting all vertices, and returning to Q.

Question: How many different Hamiltonian circuits are possible, starting at vertex Q?

Solution:

For n=5n = 5n=5 vertices, Hamiltonian circuits = (n−1)!(n-1)!(n−1)!

(5−1)!=4!=24(5-1)! = 4! = 24(5−1)!=4!=24

Since the graph is undirected, reverse circuits are the same.

Unique circuits = 24/2=12

Answer: 12

4. Counting Cycles in an Undirected Graph

The graph has vertices W, X, Y, Z and the following edges: WX, XY, YZ, XZ, WY.

Question: How many cycles exist? Remember cycles must include at least 3 vertices, and reversed cycles count as separate.

Solution:

- Cycles of length 3: WXYW, WYZW, XZYX (and their reverses: WYXW, WZYW, XZYW) → 6
- Cycles of length 4: WXZYW, WYZXW (and their reverses: WZXYW, WYZXW) → 4
- Total cycles = 6 + 4 = 10

Answer: 10

5. Traversable Graphs

In a graph, the following vertices have these edges:

- A: 3 edges, B: 4 edges, C: 5 edges, D: 2 edges, E: 1 edge, G: 3 edges
- Question: Identify the starting and ending vertices needed to traverse this graph.

Solution:

- Traversable graphs must have exactly 0 or 2 vertices with an odd degree.
- Odd-degree vertices: A (3), C (5), E (1), G (3).
- Since there are more than 2 odd-degree vertices, traversal is not possible.

Answer: NONE

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Email: info@younggates.com
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