**EXERCISE 1**

**I. VERIFICATION AND VALIDATION**

-SYSTEM 1 is missing the variable DELTA, so when entering variables a b c it will cause an error when calculating x1 and x2 because there is no variable DELTA

The formula for calculating x2 is wrong because the correct formula is: x2 = (-b - sqrt(DELTA)) / 2a not x2 = -b - sqrt(DELTA/2a)

-SYSTEM 2 runs correctly as required and does not have any errors

**II. TEST-CASES**

**a**

This code requires 2 test cases: x = 10 and x = 11 to satisfy all requirements of the code

**Test case 1**

x = 10

Expected Output: -10

Result: -10 (correct because when x = 10 it returns -x)

**Test case 2**

x = 11

Expected Output: 22

Result: 22 (correct because when x > 10 it returns 2\*x)

**b**

This sentence requires 3 test cases: x=11, x=5, x=-4 to satisfy all requirements of the function

**Test case 1**

x = 11

Expected Output: 22

Result: 22

Because 11>10 so the result will be 22 (2\*x)

**Test case 2**

x = 5

Expected Output: -5

Result: -5 because 0<5<10 so returns -x

**Test case 3**

x = -4

Expected Output: -8

Result: -8 (correct because when x = 10 it returns -x)

Because it belongs to the else case returning x\*2

**c**

This sentence requires 3 test cases: x=8, x=-5, x=22 to satisfy all requirements of the function and check for errors

**Test case 1**

x = 8

Expected Output: 16

Result: 16

Correct because 8<10 so returns 2\*x

**Test case 2**

x = -5

Expected Output: 5

Result: -10

Wrong because x=-5 receives the condition x<10 before receiving the condition x<2 so all x<2 will return the condition of x<10 because it stands before x<2

**Test case 3**

x = 22

Expected Output: 44

Result: 44 (correct because when x = 10 it returns -x)

Correct because it belongs to the else case which is >10 so returns 2\*x

**d**

This sentence the test cases will focus on the log function of the math.h library because no matter what the comparison result is, the result is always x\*2

**test case 1**

x=0

Expected Output: Undefined behavior (log returns value -INFINITY)

Output: 0

Set value x=0 so that log(x\*x\*cos(x)) = log(0) obtains error result but the math.h library of c++ returns the value of log(0) as -INFINITY so -INFINITY<0 and the code does not occur error

**test case 2**

x=180

Expected Output: Undefined behavior (log returns value NaN)

Output: 360

Set value x= 180 so that log(x\*x\*cos(x))=log(-32400) and log will return value NaN or not a number but according to IEEE 754 standard any comparison corresponding to NaN will return false result so the code still runs correctly

**e**

This sentence the test cases will focus on combinations of 3 numbers with different arrangements and values

**test case 1**

num1 = 1

num2 = 2

num3 = 3

Expected Output: 3

Output: 3

The numbers are arranged in increasing order, runs correctly because the numbers do not overlap

**test case 2**

num1 = 3

num2 = 2

num3 = 1

Expected Output: 3

Output: 3

The numbers are arranged in decreasing order, runs correctly because the numbers do not overlap

**test case 3**

num1 = 1

num1 = 3

num1 = 2

Expected Output: 3

Output: 3

The numbers are arranged randomly, runs correctly because the numbers do not overlap

**test case 4**

num1 = 2

num2 = 1

num3 = 2

Expected Output: 2

Output: 0

There are 2 numbers the same and larger than the remaining number, runs wrong because 2 numbers the same and larger than the remaining number do not satisfy the greater comparison so the max value does not change

**test case 5**

num1 = 1

num2 = 2

num3 = 2

Expected Output: 2

Output: 0

There are 2 numbers the same and larger than the remaining number, runs wrong because 2 numbers the same and larger than the remaining number do not satisfy the greater comparison so the max value does not change

**test case 6**

num1 = 2

num2 = 1

num3 = 1

Expected Output: 2

Output: 2

There are 2 numbers the same and smaller than the remaining number, runs correctly because 2 numbers the same and smaller than the remaining number do not satisfy the greater comparison so the max value will be assigned correctly

**test case 7**

num1 = 2

num2 = 2

num3 = 1

Expected Output: 2

Output: 0

There are 2 numbers the same and larger than the remaining number, runs wrong because 2 numbers the same and larger than the remaining number do not satisfy the greater comparison so the max value does not change

**test case 8**

num1 = 2

num2 = 2

num3 = 2

Expected Output: 2

Output: 0

There are 2 numbers the same, runs wrong because 3 numbers the same do not satisfy the greater comparison so the max value does not change

**test case 9**

num1 = -2

num2 = -2

num3 = -2

Expected Output: - 2

Output: 0

There are 2 negative numbers the same, runs wrong because 3 numbers the same do not satisfy the greater comparison so the max value does not change

**III. PRATICE 1**

**1. Problem Description**

The provided C++ program solves a quartic equation of the form ax4+bx2+c=0 ax^4 + bx^2 + c = 0 ax4+bx2+c=0, where a a a, b b b, and c c c are coefficients input by the user. The goal is to find all real solutions for x x x. Since the equation only contains even powers of x x x, we can substitute y=x2 y = x^2 y=x2, reducing it to a quadratic equation: ay2+by+c=0 ay^2 + by + c = 0 ay2+by+c=0. The program computes the real roots of x x x based on the roots y y y of this quadratic equation.

**Input:**

Three real numbers of type double: a a a, b b b, and c c c, representing the coefficients of the equation ax4+bx2+c=0 ax^4 + bx^2 + c = 0 ax4+bx2+c=0.

**Output:**

The number of real solutions and the list of real solutions (if any).

Specific cases:

If a=0 a = 0 a=0, b=0 b = 0 b=0, c=0 c = 0 c=0: the equation has infinitely many solutions (returns -1).

If a=0 a = 0 a=0, b=0 b = 0 b=0, c≠0 c \neq 0 c=0: there are no solutions (returns 0).

If a=0 a = 0 a=0, b≠0 b \neq 0 b=0: solve the linear equation by+c=0 by + c = 0 by+c=0, where y=x2 y = x^2 y=x2. If y<0 y < 0 y<0, there are no real solutions; if y≥0 y \geq 0 y≥0, there are two solutions: x=y x = \sqrt{y} x=y​ and x=−y x = -\sqrt{y} x=−y​.

If a≠0 a \neq 0 a=0: solve the quadratic equation ay2+by+c=0 ay^2 + by + c = 0 ay2+by+c=0 using the quadratic formula: y=−b±b2−4ac2ay = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}y=2a−b±b2−4ac​​

If Δ=b2−4ac<0 \Delta = b^2 - 4ac < 0 Δ=b2−4ac<0: there are no real solutions.

If y≥0 y \geq 0 y≥0: take the square root to obtain solutions x=y x = \sqrt{y} x=y​ and x=−y x = -\sqrt{y} x=−y​.

The maximum number of real solutions is 4 (two roots y1 y\_1 y1​, y2 y\_2 y2​, each yielding two x x x-values).

**Output Format:**

If there are infinitely many solutions: "Infinite solutions."

If there are no solutions: "No solution."

If there are n n n real solutions: "The equation has n n n real solution(s):" followed by the list of solutions.

**2. Test Cases to Verify Program Correctness**

Based on the problem description and the provided test cases, we analyze the cases to ensure the program’s correctness. The test cases should cover all special cases of the equation:

**Test Case 1: Infinitely Many Solutions**

**Input**: a=0 a = 0 a=0, b=0 b = 0 b=0, c=0 c = 0 c=0

**Expected Output**: "Infinite solutions."

**Explanation**: The equation 0x4+0x2+0=0 0x^4 + 0x^2 + 0 = 0 0x4+0x2+0=0 is true for all x x x.

**Test Case 2: No Solutions**

**Input**: a=0 a = 0 a=0, b=0 b = 0 b=0, c=1 c = 1 c=1

**Expected Output**: "No solution."

**Explanation**: The equation 0x4+0x2+1=0 0x^4 + 0x^2 + 1 = 0 0x4+0x2+1=0 reduces to 1=0 1 = 0 1=0, which has no solutions.

**Test Case 3: No Solutions (Linear Equation, y<0 y < 0 y<0)**

**Input**: a=0 a = 0 a=0, b=1 b = 1 b=1, c=1 c = 1 c=1

**Expected Output**: "No solution."

**Explanation**: The equation 0x4+x2+1=0 0x^4 + x^2 + 1 = 0 0x4+x2+1=0 becomes y+1=0 y + 1 = 0 y+1=0, so y=−1 y = -1 y=−1. Since y=x2≥0 y = x^2 \geq 0 y=x2≥0, there are no real solutions.

**Test Case 4: Two Real Solutions**

**Input**: a=0 a = 0 a=0, b=1 b = 1 b=1, c=−4 c = -4 c=−4

**Expected Output**: "The equation has 2 real solution(s): 2 -2"

**Explanation**: The equation 0x4+x2−4=0 0x^4 + x^2 - 4 = 0 0x4+x2−4=0 becomes y−4=0 y - 4 = 0 y−4=0, so y=4 y = 4 y=4. Thus, x=4=2 x = \sqrt{4} = 2 x=4​=2, x=−4=−2 x = -\sqrt{4} = -2 x=−4​=−2.

**Test Case 5: No Solutions (Δ<0 \Delta < 0 Δ<0)**

**Input**: a=1 a = 1 a=1, b=2 b = 2 b=2, c=2 c = 2 c=2

**Expected Output**: "No solution."

**Explanation**: The equation x4+2x2+2=0 x^4 + 2x^2 + 2 = 0 x4+2x2+2=0 becomes y2+2y+2=0 y^2 + 2y + 2 = 0 y2+2y+2=0. Compute Δ=22−4⋅1⋅2=4−8=−4<0 \Delta = 2^2 - 4 \cdot 1 \cdot 2 = 4 - 8 = -4 < 0 Δ=22−4⋅1⋅2=4−8=−4<0, so there are no real solutions.

**Test Case 6: Two Real Solutions**

**Input**: a=1 a = 1 a=1, b=−2 b = -2 b=−2, c=1 c = 1 c=1

**Expected Output**: "The equation has 2 real solution(s): 1 -1"

**Explanation**: The equation x4−2x2+1=0 x^4 - 2x^2 + 1 = 0 x4−2x2+1=0 becomes y2−2y+1=0 y^2 - 2y + 1 = 0 y2−2y+1=0, or (y−1)2=0 (y - 1)^2 = 0 (y−1)2=0, so y=1 y = 1 y=1. Thus, x=1=1 x = \sqrt{1} = 1 x=1​=1, x=−1=−1 x = -\sqrt{1} = -1 x=−1​=−1.

**Test Case 7: Four Real Solutions**

**Input**: a=1 a = 1 a=1, b=−5 b = -5 b=−5, c=6 c = 6 c=6

**Expected Output**: "The equation has 4 real solution(s): 2 -2 1.41421 -1.41421"

**Explanation**: The equation x4−5x2+6=0 x^4 - 5x^2 + 6 = 0 x4−5x2+6=0 becomes y2−5y+6=0 y^2 - 5y + 6 = 0 y2−5y+6=0. Compute Δ=(−5)2−4⋅1⋅6=25−24=1 \Delta = (-5)^2 - 4 \cdot 1 \cdot 6 = 25 - 24 = 1 Δ=(−5)2−4⋅1⋅6=25−24=1. Roots: y1=5+12=3,y2=5−12=2y\_1 = \frac{5 + \sqrt{1}}{2} = 3, \quad y\_2 = \frac{5 - \sqrt{1}}{2} = 2y1​=25+1​​=3,y2​=25−1​​=2 For y1=3 y\_1 = 3 y1​=3: x=3≈1.732 x = \sqrt{3} \approx 1.732 x=3​≈1.732, x=−3≈−1.732 x = -\sqrt{3} \approx -1.732 x=−3​≈−1.732. For y2=2 y\_2 = 2 y2​=2: x=2≈1.41421 x = \sqrt{2} \approx 1.41421 x=2​≈1.41421, x=−2≈−1.41421 x = -\sqrt{2} \approx -1.41421 x=−2​≈−1.41421.

**Test Case 8: Two Repeated Solutions**

**Input**: a=1 a = 1 a=1, b=0 b = 0 b=0, c=0 c = 0 c=0

**Expected Output**: "The equation has 2 real solution(s): 0 0"

**Explanation**: The equation x4=0 x^4 = 0 x4=0 becomes y2=0 y^2 = 0 y2=0, so y=0 y = 0 y=0. Thus, x=0=0 x = \sqrt{0} = 0 x=0​=0, x=−0=0 x = -\sqrt{0} = 0 x=−0​=0.

TESTCASE RESULT

**Test Case 1**

a = 0

b = 0

c = 0

Expected Output: Infinite solutions.

Output: Infinite solutions.

Runs correctly because when a = 0, b = 0, c = 0, the equation ax^4 + bx^2 + c = 0 becomes 0 = 0, has infinite solutions, satisfies the condition to return -1 and print "Infinite solutions."

**Test Case 2**

a = 0

b = 0

c = 1

Expected Output: No solution.

Output: No solution.

Runs correctly because when a = 0, b = 0, c = 1, the equation 0x^4 + 0x^2 + 1 = 0 becomes 1 = 0, no real solution, satisfies the condition to return 0 and print "No solution."

**Test Case 3**

a = 0

b = 1

c = 1

Expected Output: No solution.

Output: No solution.

Runs correctly because when a = 0, the equation becomes bx^2 + c = 0, that is x^2 + 1 = 0. The value y = -c/b = -1/1 = -1 < 0, no real solution (cannot take square root of negative number), satisfies the condition to return 0 and print "No solution."

**Test Case 4**

a = 0

b = 1

c = -4

Expected Output: The equation has 2 real solution(s): 2 -2

Output: The equation has 2 real solution(s): 2 -2

Runs correctly because when a = 0, the equation becomes x^2 - 4 = 0. The value y = -c/b = -(-4)/1 = 4 >= 0, so has two real solutions x = ±sqrt(4) = ±2, satisfies the condition to return 2 solutions and print the correct values.

**Test Case 5**

a = 1

b = 2

c = 2

Expected Output: No solution.

Output: No solution.

Runs correctly because delta = b^2 - 4ac = 2^2 - 4\*1\*2 = 4 - 8 = -4 < 0. When delta is negative, the equation has no real solution, satisfies the condition to return 0 and print "No solution."

**Test Case 6**

a = 1

b = -2

c = 1

Expected Output: The equation has 2 real solution(s): 1 -1

Output: The equation has 2 real solution(s): 1 -1

Runs correctly because delta = b^2 - 4ac = (-2)^2 - 4\*1\*1 = 4 - 4 = 0. The value y1 = y2 = (-(-2))/(2\*1) = 2/2 = 1 >= 0. Since y1 = y2, only take two solutions x = ±sqrt(1) = ±1, satisfies the condition to return 2 solutions and print the correct values.

**Test Case 7**

a = 1

b = -5

c = 6

Expected Output: The equation has 4 real solution(s): 2 -2 1.41421 -1.41421

Output: The equation has 4 real solution(s): 1.73205 -1.73205 1.41421 -1.41421

Runs wrong because the output does not match the expectation. Calculation: delta = b^2 - 4ac = (-5)^2 - 4\*1\*6 = 25 - 24 = 1. y1 = (-(-5) + sqrt(1))/(2\*1) = (5 + 1)/2 = 3, y2 = (5 - 1)/2 = 2. The solutions must be x = ±sqrt(3) ≈ ±1.73205 and x = ±sqrt(2) ≈ ±1.41421. However, the program prints in the wrong order or the values ±sqrt(3) (1.73205) are listed before ±sqrt(2) (1.41421), while the expectation is 2, -2 (i.e. ±sqrt(4), but the equation does not give y = 4). Possibly the source code does not sort the solutions in the correct order or has a logic error when assigning solutions.

**Test Case 8**

a = 1

b = 0

c = 0

Expected Output: The equation has 2 real solution(s): 0 0

Output: The equation has 2 real solution(s): 0 -0

Runs correctly because delta = b^2 - 4ac = 0^2 - 4\*1\*0 = 0. The value y1 = y2 = (0 + 0)/(2\*1) = 0 >= 0. The solutions are x = ±sqrt(0) = 0, -0 (overlapping, but the program returns both), satisfies the condition to return 2 solutions. Note: 0 and -0 are equivalent, so the output matches the expectation.