TRANSPORT AND TELECOMMUNICATION INSTITUTE

ENGINEERING FACULTY

Laboratory work N1

Course: **Programming**

Theme: **Linear programs. Working with mathematical functions.**

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Contents

1. Laboratory work task

Create an algorithm that calculates values *z1* and *z2* by formulas given in individual task.

2. Individual task

Individual task number is being defined by formula: **taskNr = studentCode % taskVarCount**

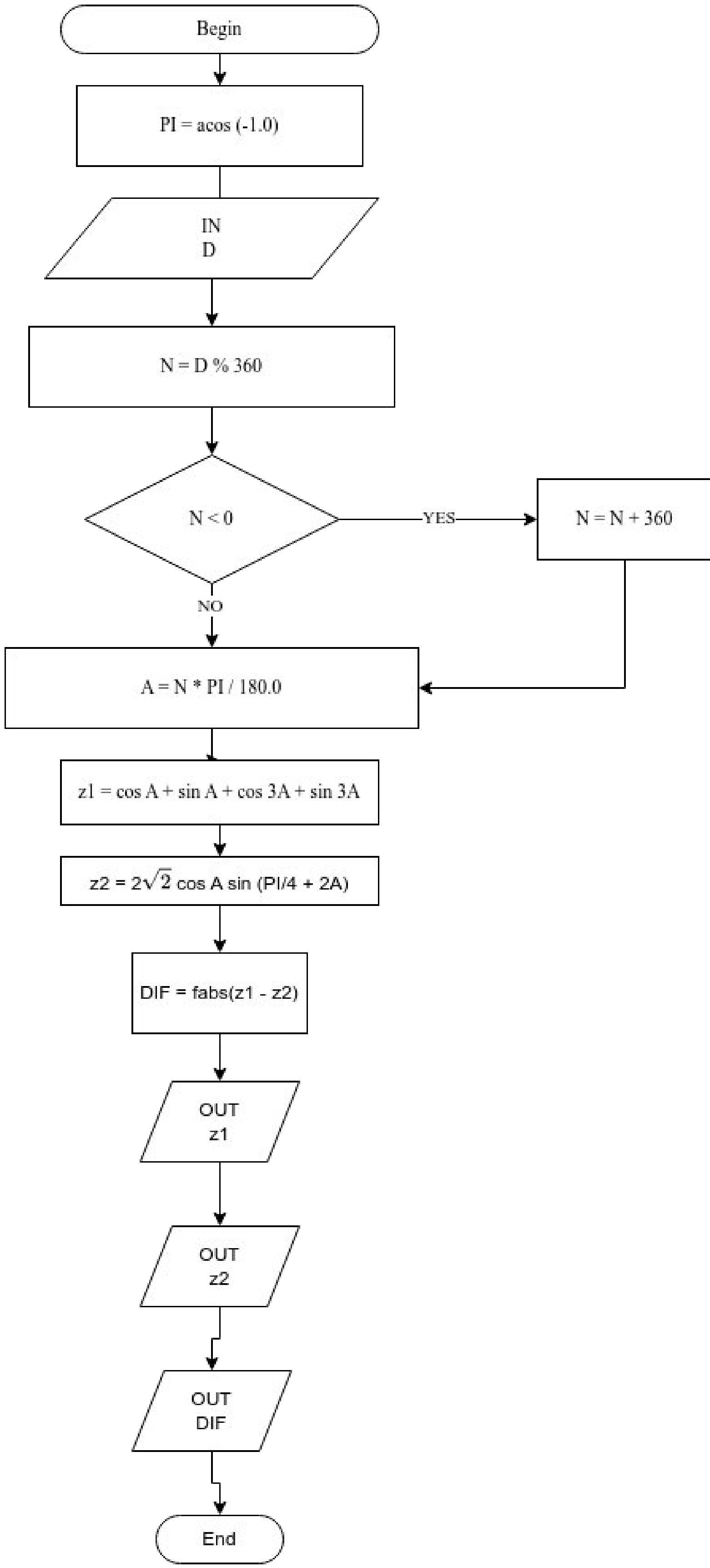
93642 % 20 = 2

Z1 = $\cos\alpha + \sin\alpha + \cos 3\alpha + \sin 3\alpha$

Z2 = $2\sqrt{2} \bullet \cos\alpha \bullet \sin\left(\frac{\pi}{4} + 2\alpha\right)$

Create a console application in C/C++ based on created algorithm that calculates *z1* and *z2* by given formulas. Output calculation results to a screen (if calculations are made correctly then *z1* and *z2* should be equal, difference is allowed in last digits after point).

3. Algorithm

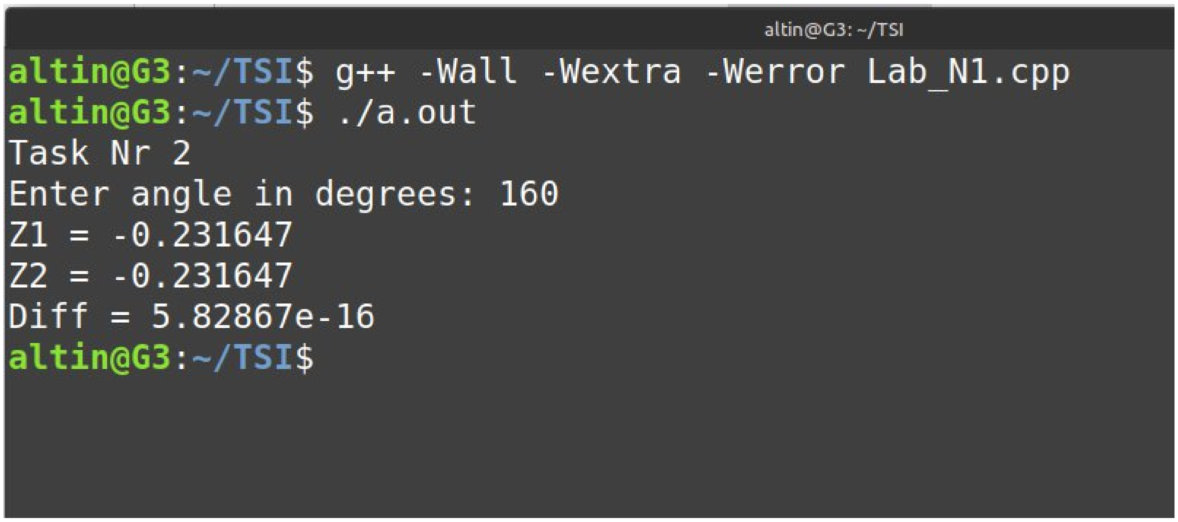


Pic. 1. **Algorithm data flow**

4. Source code

```
#include <iostream>
#include <cmath>

int main(void)
{
   int            input_degr;
   int            normalized_input;
   double         alfa_rad;
   double         z1;
   double         z2;
   double         diff;

   const double   PI = acos(-1.0);

   std::cout << "Task Nr " << 93642%20 << std::endl;
   std::cout << "Enter angle in degrees: ";
   std::cin >> input_degr;

   normalized_input = input_degr % 360;
   if (normalized_input < 0) normalized_input += 360;
   alfa_rad = normalized_input * PI / 180.0;

   z1 = cos(alfa_rad) + sin(alfa_rad) + cos(3 * alfa_rad) + sin(3 * alfa_rad);
   z2 = 2 * sqrt(2) * cos(alfa_rad) * sin(PI / 4 + 2 * alfa_rad);
   diff = fabs(z1 - z2);

   std::cout << "Z1 = " << z1 << std::endl;
   std::cout << "Z2 = " << z2 << std::endl;
   std::cout << "Diff = " << diff << std::endl;

   return (0);
}
```

5. Running program example



Pic. 2. **Running program example**

6. Testing

Table **1**

Input	Z1	Z2	Difference
-360	2	2	0
-90	3.33067e-16	3.67394e-16	3.43271e-17
-45	-1.41421	-1.41421	1.33227e-15
-705	2.63896	2.63896	4.44089e-16
0	2	2	0
45	1.41421	1.41421	4.44089e-16
60	0.366025	0.366025	1.66533e-16
90	-2.22045e-16	-1.22465e-16	9.95799e-17
180	-2	-2	0
200	-2.64774	-2.64774	4.44089e-16
1300	-1.77486	-1.77486	2.44249e-15

7. Conclusions

Algorithmic flow:

- Normalize input_degr into [0, 360) → normalized_input.(Helps reduce rounding errors)
- Convert to radians: alfa = normalized_input * PI / 180.
- Compute two mathematically-equivalent expressions:
- z1 = cos(alfa) + sin(alfa) + cos(3alfa) + sin(3alfa)
- z2 = 2 * sqrt(2) * cos(alfa) * sin(PI/4 + 2*alfa)
- Compute diff = |z1 - z2|.
- Print z1, z2, diff.

Machine epsilon (double precision): eps ≈ 2.22e-16. Any single floating-point operation can introduce relative errors on the order of eps.

Each trigonometric evaluation (cos, sin) returns an approximate result with error roughly O(eps) relative to the true value. The subsequent arithmetic (adds, multiplies) accumulates and propagates those errors.

When the true result is 0 (for example at alfa = 90° both expressions are exactly 0 analytically), the computed terms (e.g., cos(pi/2)) are tiny non-zero values of ±O(eps). Summing several small terms with mixed signs can leave a residual of order a few × eps (e.g., -2.22e-16), and two different algebraic forms (z1 vs z2) do different sequences of operations => different rounding paths and slightly different residues (e.g., -2.22045e-16 vs -1.22465e-16). Their difference is about the same order as eps (≈ 1e-16).

Operation count matters: z1 computes 4 trigonometric calls + 3 additions; z2 uses fewer or different operations (including a multiplication by sqrt(2) and a single trig). Different operation trees produce different rounding errors.

Given expressions are matematically identical and can be mutated to one from other with trigonometric transformations.

Conclusion: A difference is expected and is numerical noise, not a correctness bug.