VORTEX 13.0

CODATHON ROUND 1

Date:
Duration: 90 min

I : Nothing But the Basics

Q.1 You Assumed Too Much — **- any 1 (5 marks)**

Let's start with something simpler, something you've been comfortable with for a decade now, something you've probably done so often that it now runs quietly in the back of your mind. On its own, this would be boring. And no, there is no twist. I trust you enough to believe that the core task is trivial for you.
Early processors, think of something as primitive as the Intel 8085 had no notion of division, exponentiation, or square roots. Even multiplication was not a first-class operation. Those ideas exist today only because someone once built them, painfully, out of simpler instructions.
Now imagine you are handed such a machine and asked to solve a fully coupled three-dimensional, transient, reacting multiphase heterogeneously catalyzed combustion for a moving boundary in a compressible fluid in hypersonic regime perhaps for a good measure, no scrap that. That would be unreasonable for a two-hour exam, the problems below are deliberately simple. The effort required to solve them should feel…. disproportionate.

A) Compute √x (x>0) using only basic arithmetic and loops; no `sqrt`, `**`, `pow`, or any libraries; your method must converge.

B) Implement abs(x) without using <, >, if, or any mathematical libraries.

C) Implement max(a, b) without <, >, if, or any built-in max.

D) Compute division a / b using only +, -, and * without using any in built function or "/" or "//" or "%" or if else.

NOTE: For every additional sub-question you solve, that question carries 2.5× marks.
Fortunately, you won't need to do this again. Someone else already suffered so you wouldn't have to.
This is the quiet difference between *imperative knowledge*: knowing **how** to make something work step by step and *declarative knowledge:* knowing **what** result you want and trusting an abstraction to deliver it. This question briefly drags you back to the former, just to remind you what the latter is built on.

Q.2 Scientific Computing, Unwrapped — **- any 1 (5 marks)**

Now that you are done with the simple questions, let's dive a bit deeper.

Let's solve something we, as engineers, take a certain pride in something that is often presented as elegant, and effortless; something that **lesser mortals cannot even comprehend** to understand. Don't worry you will not be asked to derive or implement a fully coupled pressure-velocity solver, nor a large-scale constrained optimization routine for a nonlinear boundary-value problem with convergence proofs. That would be unreasonable given this is just a vortex event.
Instead, we will look at something far more fundamental.

Modern scientific libraries such as NumPy and SciPy offer one-line solutions for tasks. Each such call, however, expands into a carefully engineered sequence of elementary arithmetic and logical operations.In this question, you must implement one such operation from scratch, without using any built-in mathematical or scientific library functions.

All design choices are left to you and will be evaluated.
A) Implement a function that computes the definite integral of a real-valued function using only basic arithmetic, loops, and conditionals.

$$\int_a^b f(x)\,dx$$

B) Find the gradient $\nabla f(x)$ at discrete points for any given function without using any **in built/library based function.** Note: input will be an array of sample points for function, output should be an array with computed gradients.

C) Given experimental data (x_i, y_i) fit a model of your choice by minimizing an error measure without using any **in built/library based** regression, optimization, or curve-fitting routines.

II : What a Bit Means

Q.3 - 3 marks

A submarine sonar system encodes a message as a sequence of integers. The receiver accepts a message only if:

"The XOR of all numbers that are one less than a prime equals the XOR of all numbers that are one more than a prime."
XOR compares two inputs bit by bit and returns True only when they differ. It is commonly used to combine information in a reversible way when one input is known.

```
>> True ^ True
False
```

```
>> True ^ False
True
```

Which sequence passes the Prime-Echo rule?

A) 6, 18, 12, 30, 42
B) 8, 10, 12, 14, 16
C) 4, 6, 8, 10, 12
D) 10, 12, 14, 16, 18

Q.4 -3 marks

Decode. Let me know what I have written. Rate the joke. Encode the rating.

Code is also expected.

Note: The binary code is 8 bit encoded. All the letters are in uppercase.

Hint: chr(65) = "A"; ord("A") = 65

Element	Decimal
Empty space	32
:	58
.	45

“01010100010010000100010101010010010001010010000001000001010100100100010100100000
00011000100110000000100000010101000101100101010000010001010101001100100000000100111
10100011000100000001010000010001010100111101010000010011000100010100100000000100100
10100111000100000001010100010010000100010100100000001010111010011110101001001001 10
00100010000011101000100000001010100010010000100111101010011010001010010000000101011
10100100000100111100100000010101010100111001000100010001010101001001010011010101 0
00100000010100111001000100001000000100001001001001010011100100000010101001001011 00
10010000000100000101001110010001000010000000101010001001000010011110101001101000 10
10010000000101011101001000010011110010000000100010001001111010011100101010000101 11
0”

III : And you thought Integers were elementary.

Q.5 **-3 marks**

Three underwater acoustic buoys **A**, **B**, and **C** detect a whale’s sonar ping.
Each buoy records arrival times on a 59-second circular clock, chosen to fit within limited onboard storage and power constraints. The recorded values are: TA = 17, TB = 52, TC = 41
Let **T** denote the true emission time of the whale’s ping. If the whale is somewhere in the region, then the true emission time is T.
Because sound takes time to travel through water, each buoy experiences an **integer propagation delay dA, dB, dC**. Signals that would require a delay greater than 50 seconds are assumed to be too weak, too dispersed, or absorbed by the environment, and are therefore not registered as valid whale detections (they are treated as noise).
Determine which emission time T (if any) is consistent with all three buoy measurements and the delay constraints.

A) 21
B) 24
C) 28
D) 46

Q.6 Marine Population Dynamics & Cycles **-3 marks**

A marine biologist is studying the population of a plankton species in a closed ocean basin. The population evolves in discrete time according to the logistic growth model: x(t+1) = r . x(t) . (1 − x(t))
where x(t) represents the normalized population size at time t, and r is a positive growth parameter that depends on environmental conditions such as nutrient availability and water temperature.
The initial population is: x(0) = 0.4
After observing the system for a long time, the biologist notices that the population does **not** settle to a single steady value. Instead, it **oscillates forever between exactly(numerical values must be considered round about) two distinct population levels**, forming a stable cycle of period 2.
Which value of the growth parameter r produces this behavior?
If you plot the population growth wrt iteration/time u get **3 more marks!**

If you plot r wrt no of cycles you get **3 more marks**!

Options

A) r = 2.556

B) r = 3.245

C) r = 3.531

D) r = 3.861

Q.7 **-3 marks**

The annual interest rate of a savings account is 4.1 %. John has 10,000 dollars in his account, and aims at saving 50,000 dollars within 5 years by depositing a fixed amount of money to his account at the beginning of each year, including this year. How much money does John need to save each year in order to achieve his goal?

a. 8992.32

b. 7554.97

c. 6686.20

d. 7783.46

Q.8 **-3 marks**

You are piloting a small submersible that starts at Reef Level 1 and wants to reach Reef Level 25 (levels numbered 1.25). On each move you may ascend +1 level or +2 levels.
Some reef levels hide dangerous whirlpools: any level divisible by 3 (3, 6, 9, …, 24) initially contains a whirlpool. Whenever your sub stops at such a whirlpool level for the first time, a current instantly pushes it back to the level it occupied immediately before the move; after that single push the whirlpool calms and will not push again on later visits. Each attempt (whether it advances you or results in being pushed back) counts as one move. Choice sequences are distinguished by the series of +1/+2 choices you make (including failed attempts into whirlpools).

Question: How many distinct sequences of moves (each move is "+1" or "+2") will get the submersible to exactly Reef Level 25?

IV : Trivial Tasks

Q.9 Optimise. **-3 marks**

In engineering practice, we often know more about a problem than we admit.
Sometimes the domain of interest is already bounded. Sometimes the function is smooth and unimodal. And very often, the bottleneck is not *correctness*, but *how we evaluate an expensive function*.
The code below implements an **equal-interval search method** to locate the minimum of a one-dimensional function `f(x)` over a known interval `[a,b]`, assuming a single minimum exists within the interval. The code is self explanatory to understand the algorithm.
This code is for finding minima for 1D function with known Interval of Uncertainty.
Reduce the computational time:

```
def eism(f, lower_bound, upper_bound, tol=1e-5):
    if (upper_bound-lower_bound) <= tol:
        if f(lower_bound) < f(upper_bound):
            return lower_bound
        else:
            return upper_bound
    x1 = lower_bound + (upper_bound-lower_bound)/3
    x2 = upper_bound - (upper_bound-lower_bound)/3
    f1 = f(x1)
    f2 = f(x2)
    while (upper_bound-lower_bound) > tol:
```

```
    if f1 < f2:
      upper_bound = x2
      x1 = lower_bound + (upper_bound-lower_bound)/3
      x2 = upper_bound - (upper_bound-lower_bound)/3
      f1 = f(x1)
      f2 = f(x2)
    else:
      lower_bound = x1
      x1 = lower_bound + (upper_bound-lower_bound)/3
      x2 = upper_bound - (upper_bound-lower_bound)/3
      f1 = f(x1)
      f2 = f(x2)
  if f1 < f2:
    return x1
  else:
    return x2
```

Q.10 Automation - 5 marks

It is easy to forget how powerful programming can be when reduced to small, repetitive tasks. Much of what we do daily: assigning identifiers, formatting records, enforcing conventions; is not difficult, merely tedious. And tedious work is precisely what machines are good at.

An academic publisher assigns **Digital Object Identifiers (DOIs)** to all research articles it publishes. Rather than doing this manually, the publisher requires a program that generates a DOI string from basic bibliographic information.

Each paper is described by:

- Year of publication (YYYY)

Journal code: a 4-character code derived from the journal name as follows:

- if the journal name consists of **one word**, use its **first four letters**;
- if the journal name consists of **two words**, use the **first two letters of each word**;
- if the journal name consists of **four words**, use the **first letter of each word**.
- Volume number (integer)
- Issue number (integer)
- First author's first name
- First author's surname
- Paper serial number within the issue (2 digits)

The DOI must follow the format:
https://doi.org/10.1038/YYYY.jcode.VV.II.ffssNN
Example:
For a paper published in "2024", journal code "CHEM", volume "7", issue "3", first author "Pranoy Roy", serial
number "05", the DOI should be: https://doi.org/10.5678/2024.chem.07.03.prro05
Write a program to generate the DOI for a given paper.

This concludes Round 1, a preliminary filter, not a measure of how much you know, but of how you think.
For some of you, this is the end.
For the rest, this is only the beginning.