

Midterm Exam (part 1) - Computational Physics II

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SCORE: 7.7

Date: Tuesday 8 April 2025 Duration: 45 minutes

Credits: 10 points (5 questions) Type of evaluation: Midterm Exam

Provide concise answers to the following items.

1. (2 points) Trapezoidal method for ordinary differential equations (ODEs)

(a) Explain how the trapezoidal method for solving ODEs works.

Trapezoidal Method is a ^{average.} combination of the implicit and explicit Euler method. Taking an average of both of them to improve the solution approximation. ^{to 2nd order.} where the explicit Euler method is dependant on the step itself and the implicit Euler method depends on the next step. It is a second order method.

(b) Consider the radioactive decay ODE with decay constant, α . If there are $N(t)$ radioactive nuclei at time t and N_0 at $t = 0$, and if their rate of decay ($-dN/dt$) is proportional to the number of undecayed nuclei, then:

$$\frac{dN}{dt} = -\alpha N$$

Indicate the slope and explain how the trapezoidal formula would be implemented in Python.

In the equation

$$\frac{dN}{dt} = -\alpha N$$

↓
slope

The RHS of the equation is the slope as it can be treated as a linear relation.

Initialisation?

Show trapezoidal implementation

① We need to define the slope function and get the initial conditions alongside the t axis.

② Define the trapezoidal integrator ^{how?} and call the function to approximate our solutions vector. ^{how?}

③ Get the solution and analyse?

2. (2 points) SLURM

(a) Describe the role of SLURM in a high-performance computing (HPC) environment.

Slurm is a package or library installed in almost every HPC. Its function is to derive and manage jobs and resources allocations for each user. One of its commands can be:
squeue; scontrol; salloc

(b) Provide an example of how resource requests are specified in a SLURM job script (e.g. when requesting a specific number of CPU cores and memory in a partition).

#!/bin/bash

#SBATCH --job-name = job1

#SBATCH --partition = cpu

#SBATCH --cpus-per-task

#SBATCH --number-of-cores=1

#SBATCH --mem=16

you can also define time

#SBATCH --time = h:m:s

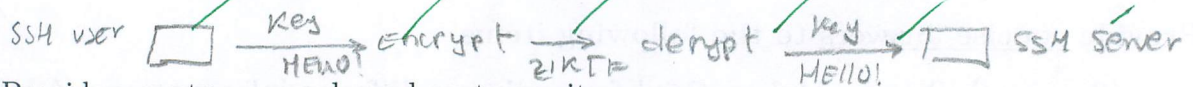
#SBATCH --output = job1.out

#SBATCH --error = job1.err

3. (2 points) Secure Shell (SSH) protocol

(a) Briefly explain what the SSH protocol is and how it works.

Secure System Host? ~~X~~ / don't remember H. But it's a protocol to connect to another device via Internet, creating a secure connection inside an insecure channel.



(b) Provide a syntax example on how to use it.

ssh -i /key/path username@ssh-server

4. (2 points) Object-oriented programming (OOP)

(a) List two key differences between the @classmethod and @staticmethod decorators.

→ Class methods interact directly with the class variables and static methods not have a directly connection.

→ Static methods can be seen as 'preprocessing' method since you give them arbitrary inputs and not memory allocated as in class methods.

(b) Explain the concept of encapsulation in object-oriented programming.

-1 Encapsulation is the form of grouping or merging different functions or code to a single purpose in a defined environment? even as it can be needed to the same purpose both different forms. ~~X~~

5. (2 points) Python parallelisation

-0.5 (a) Sequentially applying an edge-detection filter to high-resolution medical images to highlight anatomical structures takes a long time. Explain how the Python's multiprocessing module can help improve the performance of this image filtering task.

Since this is a complex repetitive task, using a single instruction but multiple data (SIMD) it can be improved by parallelising the process with multiprocessing as assigning a for loop per each image on the pool.

(b) Describe the key steps involved in implementing a parallelised algorithm that uses multiprocessing to apply the edge-detection filter to these images.

① Define the edge-detection function filter → which one?

② Determine number of cores → how?

③ Create the jobs pool with mp.Pool

④ Map the processes to the pool and the range of jobs, also the cores to be used. What operations are parallelized?

⑤ Optimize by analyzing the and number of cores performance