

FIZ 241E Term Project – Fall 2022

Please read the following instructions very carefully before proceeding to the question.

- You **must** use C++ for coding. You are **not** allowed to use pointers, classes, structs, and the command “goto”. You **must** use **valarrays** if you need to use arrays (vectors, etc.).
- Name your file as your **İTÜ e-mail username** (e.g. birkandant.cpp) and **upload your C++ file** (**not** a PDF or other types) as your project.
- You **must** upload your project as a **C++ file (with a .cpp extension)** to Ninova **before** the deadline.
- Uploading the **correct** file to Ninova before the deadline is **your** responsibility.
- If you fail to upload your project because of a Ninova malfunction, send me an e-mail (birkandant@itu.edu.tr) with your file from your İTÜ account **before** the deadline.
- Do **not** display (cout, etc.) anything in the functions.
- Do **not** use less or more **input/output variables** in the functions other than the ones required in the question. You can declare local variables (that can be used only in that function) if you need them.
- Do **not** write additional features, functions to the program, just follow the question.
- Do **not** use commands, variable types, or methods we did not cover in class examples.
- The first line of your code should be a **comment** line including your student number and full name. (e.g. // 090909090 Tolga Birkandan)
- You will see **XX** at the end of some function/variable names. You should **replace** them with your **initials** in capitals using the English alphabet. If you have three names use all initials. (e.g. for “Tolga Birkandan”, “fXX” will be “fTB”, for “Hüseyin Şevki Topuz”, “findmypeaksXX” will be “findmypeaksHST”)
- Use comment lines to explain:
 - o Each **loop** (e. g. // This loop calculates the sum of the elements in vector v1)
 - o Each **if** condition (e.g. // If the value of i equals to N we break the loop)
 - o At the beginning of the code (after your number and name), **summarize the whole question** in your own words using comment lines.
 - o At the beginning of each function, **summarize the work that will be done in that function** in your own words using comment lines.

You can use your notes and any online/offline documents but you are not allowed to communicate with another human being online / offline / directly / indirectly.

Please **double check** your program to make sure that you followed **all** the instructions before uploading it to Ninova. If something is **not** forbidden clearly by the above instructions or in the question, then you are **allowed** to do it.

THEORY:

Bessel functions emerge in many applications in physics and engineering. They are closely related with cylindrical symmetry.

In this project, we will study the Bessel function of the first kind. We denote this function as $J_n(x)$ or $\text{BesselJ}(n,x)$. Among many definitions, we have the integral,

$$J_n(x) = \text{BesselJ}(n,x) = \frac{1}{\pi} \int_0^\pi \cos(x \sin(\theta) - n\theta) d\theta$$

In the question below, we will find some peak values of the Bessel function of the first kind using this integral definition.

You do not need to know anything about these functions for this project, just follow the instructions in the question.

If you want to learn more about these functions, see:

Mary L. Boas, “*Mathematical Methods in the Physical Sciences*” (3rd Ed.), John Wiley&Sons Inc. (2006).

The question starts on the next page. Good luck!



QUESTION:

!!!! Please read all instructions on the first page before starting to code !!!!

- Set the number “pi” using “define”: #define pi 3.141593. Then use it whenever needed without further declaration.

The non-void function “fXX”:

Input arguments: “n” (int), “x” (double), θ (“theta”) (double)

Output argument: “res” (double)

Calculation: $\text{res} = \cos(x \sin(\theta) - n\theta)$

The non-void function “besseljXX”:

Input arguments: “n” (int), “x” (double)

Output argument: “res” (double)

Calculation:

You will calculate the “res” = BesselJ(n,x) function using its integral representation. Find (disregarding the numerical errors)

$$\text{res} = \frac{1}{\pi} \int_0^{\pi} \cos(x \sin(\theta) - n\theta) d\theta$$

using the Euler quadrature method that can be summarized as

$$\int_a^b f(z) dz = \frac{(b-a)}{M} \sum_{i=1}^M f(z_i)$$

where

$$z_i = a + (i-1) \frac{(b-a)}{M}$$

Remember that you have defined $\cos(x \sin(\theta) - n\theta)$ in the function “fXX”. You **must** use this function whenever you need the value of the function.

Use $M = 10000$.

Do not forget the factor $\frac{1}{\pi}$ in the integral representation!

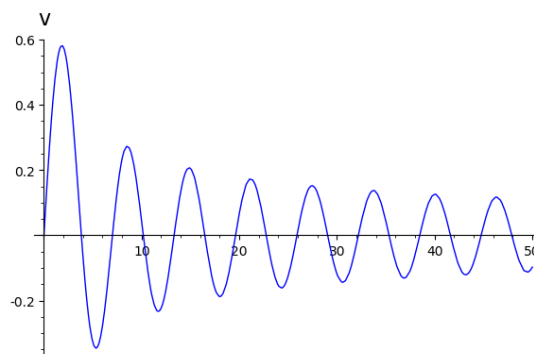
The void function “findmypeaksXX”:

Input argument: “v” (valarray vector with double numbers) (number of elements is **not** an input argument)

Output argument: “peaks” (valarray vector with double numbers) (number of elements is **not** an input argument)

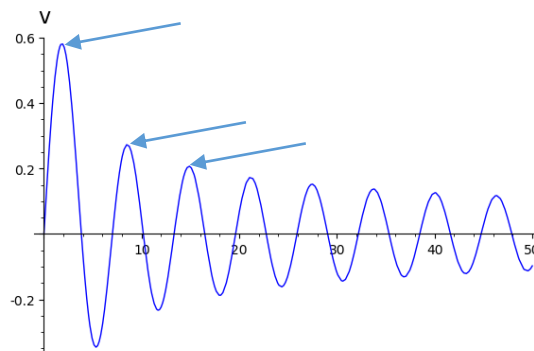
Calculation:

If you could plot the vector “v” (do not try this in the project), you would see a graph similar to the following:



Your function will find the elements in the vector “v” corresponding to **the first N peaks** and put them in the vector “peaks” (here, N is the number of elements of the vector “peaks”).

If $N = 3$, then it will find the following:



Namely, $\text{peaks}[0] = 0.581965$, $\text{peaks}[1] = 0.273398$, $\text{peaks}[2] = 0.207111$.

Attention: Assume that the first and the last terms in “v” are **not** peak values.

The main program:

- Declare and set “num1” as an integer number. (Please see the table below for its value.)
- Declare and set “num2” as an integer number. (Please see the table below for its value.)
- Declare and set “num3” as an integer number. (Please see the table below for its value.)
- Declare and set “h” as a double number. (Please see the table below for its value.)
- Declare two valarray vectors (with double numbers) “myvals” and “mybessel” with num1 elements.
- Declare a valarray vector (with double numbers) “mypeaksXX” with num2 elements.

- Declare a double number “initial” and set its value to 0.0.
- You can declare other variables if you need them.
- Form the vector “myvals”: The first element of the vector “myvals” is the number “initial”. Other elements of this vector are found sequentially as initial+h, initial+2*h, initial+3*h, etc.
- Form the vector “mybessel”: The i^{th} element of the vector “mybessel” is found using the function you defined above as `besseljXX(num3,myvals[i])`.
- Send “mybessel” and “mypeaksXX” to the void function `findmypeaksXX` and display the values of the result “mypeaksXX” on the screen one element on each line in the main program.

Attention: The program may take some time (around 10-20 seconds) to finish running depending on your computer.

Last digit of your student number	num1	num2	num3	h
0	5000	2	0	0.01
1	2000	3	1	0.02
2	3000	4	2	0.03
3	4000	5	3	0.04
4	5000	6	4	0.05
5	6000	7	5	0.06
6	7000	8	6	0.07
7	8000	9	7	0.08
8	9000	10	8	0.09
9	10000	11	9	0.15

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