



ENGR-UH 1000

Computer Programming for Engineers

Assignment 1: Civil Engineering
Case Study – Water Pressure
Exerted on a Dam

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Step 1: Problem Identification and Statement

Using the polynomials that represent the Water exerts pressure on the upstream face of a dam, print a table using units of meter of water elevation and Newton of force. Asking the user to input the values for the channel base width, channel depth, water elevation above channel bottom, distance between edge to the bank of channel. Also find the force of pressure and calculate force for a range of water elevations.

Step 2: Gathering Information

Water exerts pressure on the upstream face of a dam as shown in figure 1. The pressure can be characterized by:

$$p(z) = \rho g(D - z) \quad (1)$$

where $p(z)$ = pressure in pascals (or N/m²) exerted at an elevation z meters above the reservoir bottom; ρ is the density of water, which for this problem is assumed to be a constant 1000 kg/m³; g is the acceleration due to gravity (9.81 m/s²); and D is the elevation (in m) of the water surface above the reservoir bottom.

According to equation (1), pressure increases linearly with depth, as depicted in Figure 1-a. Omitting atmospheric pressure (because it works against both sides of the dam face and essentially cancels out), the total force f_t can be determined by multiplying pressure times the area of the dam face (as shown in Figure 1-b). Because both pressure and area vary with elevation, the total force is obtained by evaluating

$$f_t = \int_0^D \rho g w(z)(D - z) dz \quad (2)$$

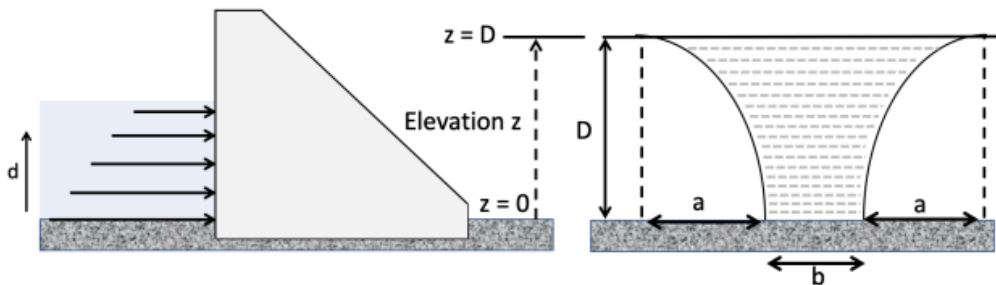


Figure 1: Water exerting pressure on the upstream face of a dam: (a) side view showing force increasing linearly with depth; (b) front view showing width of dam in meters.

where $w(z)$ = width of the dam face (m) at elevation z (Figure 1-b).

Assume that the width of the channel is modeled to be a second order polynomial as shown here:

$$w(z) = (2az^2/D^2) + b \quad (3)$$

Where a is distance from edge of the channel to the bank of the channel, z is distance from channel bottom, D is depth of the channel, b is width of the channel base, and $w(z)$ is width of water.

Combining equations (1), (2), and (3), we get:

$$f(d) = \rho g \int_0^d (d - z) * ((2az^2/D^2) + b) dz \quad (4)$$

This integration yields the following equation:

$$f(d) = \rho g * [ad^4/6D^2 + bd^2/2] \quad (5)$$

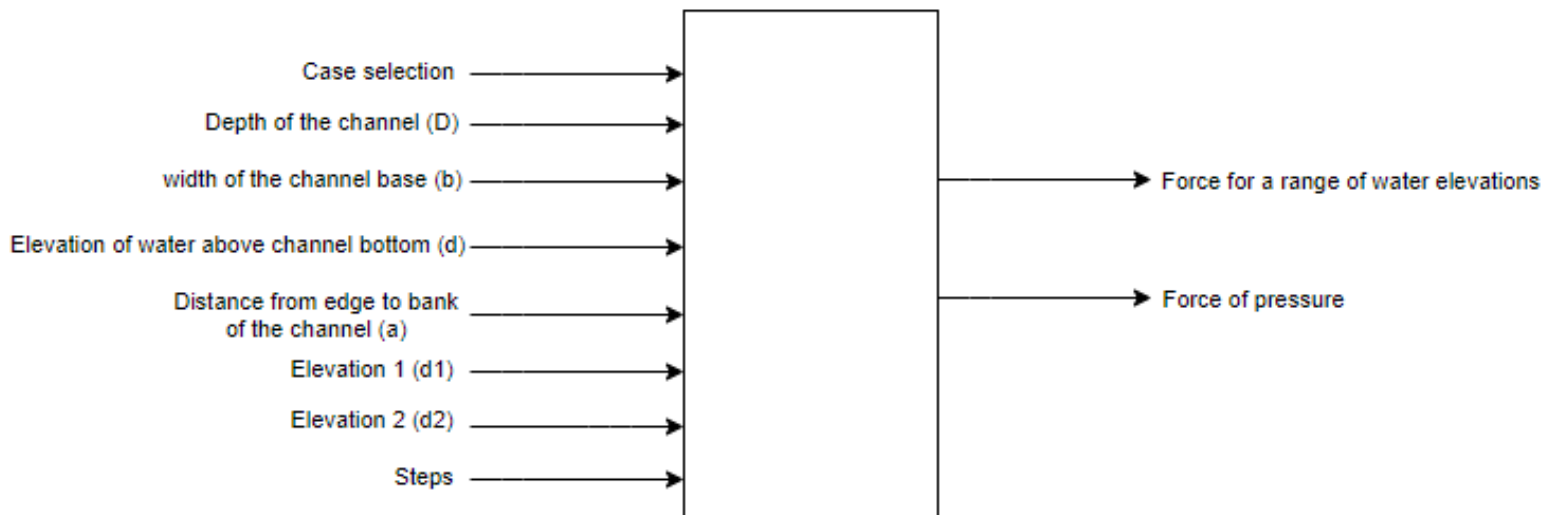
This equation will calculate force on the dam at specific locations depending on the depth of the channel (D), width of the channel base (b), elevation of water above channel bottom (d), distance from edge to bank of the channel (a), and knowing that $g=9.81$ N/kg and density of the water is 1000kg/m^3 .

Input/Output Description

The following I/O diagram shows the user input that represents the case selection, Depth of the channel (D), width of the channel base (b), Elevation of water above channel bottom (d), distance from edge to bank of the channel (a), Elevation 1 (d1), Elevation 2 (d2), Steps. The output is the table of force of pressure and calculate force for a range of water elevations. We can use the built-in data type Double for input and output objects.

The program menu contains three options that the user can choose from: the first option (1) is to calculate the force of the dam, the second option is to calculate the force for range of water elevation, and the last one is to exit the program.

- 1) Calculating the force on the dam
- 2) Calculating the force for a range of water elevation
- 3) Exit the program



Step 3: Test Cases

Test case 1.a: Invalid function selection (selection input error):

The program starts by asking the user which function he want to use:

- 1) Calculating the force on the dam
- 2) Calculating the force for a range of water elevation
- 3) Exit the program

In case the user chooses any unidentified option, the program will print an error message: Please choose one of the option (1,2,3).

Test case 1.b: invalid input type (TypeError)

When the program asks the user to enter the inputs, whether the task calculates the force or the force range, the program will ask about a set of double variables. If the user skipped input or entered a non-numerical data type, the program will print an error message: Please enter a numerical value.

Test case 1.c: Negative value for elevation (LogicError)

The user will input a for the selection process. For instance:

The user enters the values $D=10$, $b=10$, $d=-10$, $a=10$, and the output should be an error message: Please enter a positive value.

Test case 1.d: Depth value of the channel equals zero (MathError)

In case the user enters $D=0$, the program will print the error message: D must be a positive value

Test case 2: Force for the elevation:

The user should input 1 for the selection process:

- 1) Calculating the force on the dam
- 2) Calculating the force for a range of water elevation
- 3)Exit the program

Please choose a task: 1

The Depth Of The Channel:

3

Width Of The Channel Base:

5

Elevation Of Water Above Channel Bottom:

4

Distance From Edge To Bank Of The Channel:

3

Force: 531920

Test case 3: range of forces for a range of elevations

The user should input 3 for the selection process. For instance:

The Depth Of The Channel:

10

Width Of The Channel Base:

4

Elevation Of Water Above Channel Bottom:

1

Second Elevation Of Water Above Channel Bottom:

9

Distance From Edge To Bank Of The Channel:

6

Elevation	:	Force
1	:	19718.1
2	:	80049.6
3	:	184526
4	:	339034
5	:	551812
6	:	833458
7	:	1.19692e+06
8	:	1.6575e+06
9	:	2.23285e+06

Test case 4: Exit the program

The user should input 3 to exit the program.

Then the program should print the message "Terminating the Program" and exit the program

Step 3: Algorithm Development

Algorithm design:

```
Declare constant double global variable g = 9.81;
Declare constant double global variable p = 1000
Declare integer global variable option;

Print" 1) Calculating the force on the dam\ n 2) Calculating the force
for a range of water elevation\ n 3) Exit the program\ n"

prompt" please choose a task"

Read into value of the prompt in option variable

If option is not integer:
    Clear the cin memory

Function ForceOverDam():

    Declare global variables D, b, d, a

    Prompt" The Depth Of The Channel" newline,
    Read into D
    Prompt" Width Of The Channel Base" newline,
    Read into b
    Prompt" Elevation Of Water Above Channel Bottom" newline,
    Read into d
    Prompt" Distance From Edge To Bank Of The Channel: "newline
    Read into a

    If D is less than or equal to zero or b is less than or equal to zero or d is less
    than or equal to zero or a is less than or equal to zero:
        Clear CIN memory
    Print" Please enter positive values\ n\ n"
    Executing welcome()
    function to back to the start of the program
    Otherwise:
        declare double variable f = p* g((a *d ^ 4) / (6 *D ^ 2) + (b *d ^ 2) / 2)
    Print" Force" + f + endl

Function RangeOfForces():
    declare double variables D, b, a, d1, d2
```

```

Prompt" The Depth Of The Channel" newline,
Read into D
Prompt" Width Of The Channel Base" newline,
Read into b
Prompt" Elevation Of Water Above Channel Bottom" newline,
Read into d
Prompt" Second Elevation Of Water Above Channel Bottom: "newline,
    Read into d2
Prompt" Distance From Edge To Bank Of The Channel: "newline
Read into a

If D is less than or equal to zero or b is less than or equal to zero or d1 is less
than or equal to zero or d2 is less than or equal to zero or a is less than or equal
to zero:

    Clear CIN memory
Print" Please enter positive values\ n\ n"
Executing welcome()
function to back to the start of the program
Otherwise
if d1 >= d2:
    Clear CIN memory
Print" Second Elevation should be greater than the First Elevation\ n\ n"
Executing welcome()
function to back to the start of the program
Else:
    Print" Elevation: Force"
Assign d1 to i

Repeat as i is less than or equal to d2

Declare double variable f = p *g *((a *i ^ 4) / (6 *D ^ 2)) + (b *i ^ 2) / (2))
print i, "", f, "", newline
Increment i by one

Function Main:

    Executing welcome
function

While option is not equal to 3:

    If option = 1:

        Execute ForceOverDam
function

Execute welcome
function

Else
if option = 2:

    Execute RangeOfForces

```



```
function
Execute welcome
function
Else:

Print` Please choose one of the option(1, 2, 3)\ n\ n`
Execute welcome
function

If option = 3:

    print` Terminating the Program`
return 0
```

Step 4: Implementation

```
#include <iostream>
#include <iomanip>
#include <cmath>
#include <limits>
using namespace std;

void pow(int e, int b);
//global variables for the function variable and constant variable

int option;
const double g = 9.81;
const double p = 1000;

// welcome message function
void welcome(){
    //printing the options
    cout << " 1) Calculating the force on the dam \n 2) Calculating the force for a range of water elevation \n
3)Exit the program\n";
    // asking for the function input
    cout<< "Please choose a task: ";
    cin>> option;
    if(option != 1 || option != 2 || option !=3){
        cin.clear();
        cin.ignore(numeric_limits<streamsize>::max(), '\n');
    }
}

//force over dam function
void ForceOverDam(){
    // identifying input variables
    double D, b, d, a;
    cout<< "The Depth Of The Channel: " << endl;
    cin >> D;

    cout<< "Width Of The Channel Base: " << endl;
```

```

cin>> b;

cout<< "Elevation Of Water Above Channel Bottom: " << endl;
cin>> d;

cout<< "Distance From Edge To Bank Of The Channel: " << endl;
cin>> a;
//checking if the values are positive & validating data types
if(D <= 0 || b <= 0 || d <= 0 || a <= 0){
    cin.clear();
    cin.ignore(numeric_limits<streamsize>::max(),'\n');
    cout << "Please enter positive values\n\n";
    welcome();
}else{
    //applying the equation

    double f = p * g * ((a * pow(d,4)) / (6 * pow(D,2) ) + (b * pow(d,2)) / 2);

    cout << "Force: " << f << " \n" <<endl;
}
}

void RangeOfForces(){
    //identifying variables
    double D, b, a, d1, d2;
    long int f;
    //Inputs
    cout<< "The Depth Of The Channel: " << endl;
    cin >> D;

    cout<< "Width Of The Channel Base: " << endl;
    cin>> b;

    cout<< "Elevation Of Water Above Channel Bottom: " << endl;
    cin>> d1;

    cout<< "Second Elevation Of Water Above Channel Bottom: " << endl;
    cin>> d2;

    cout<< "Distance From Edge To Bank Of The Channel: " << endl;
    cin>> a;

    if(D <= 0 || b <= 0 || d1 <= 0 || d2 <= 0 ||a <= 0 ){
        cin.clear();
        cin.ignore(numeric_limits<streamsize>::max(),'\n');
        cout << "Please enter positive values\n\n";
    }
}

```

```

    welcome();
}else if (d1 >= d2) {
    cin.clear();
    cin.ignore(numeric_limits<streamsize>::max(),'\n');
    cout << "Second Elevation should be greater than the First Elevation \n\n";
    welcome();

}

//table for the range
cout << left << setw(10) << "Elevation" << " : " << left << setw(10) << "Force" << endl;;
for(double i = d1; i <= d2; i++){

    double f = p * g * ((a * pow(i,4)) / (6 * pow(D,2) ) + (b * pow(i,2)) / 2);

    cout << left << setw(10) << i << " : " << left << setw(10) << f << endl ;
}
}

cout << "\n\n";
}

int main() {
    // calling the welcome message
    welcome();
    while (option !=3){
        // Computation
        if (option == 1){
            //calling force over dam function
            ForceOverDam();
            welcome();
        }else if(option == 2){
            // calling range of forces function
            RangeOfForces();
            welcome();
        }else{
            // printing error message and repeating the program
            cout << "Please choose one of the option (1,2,3)\n\n";
            welcome();
        }
    }
    //program termination
    cout<< "Terminating the Program";
    return 0;
}

```

Step 5: Test and Verification

Test case 1.a: Invalid function selection (selection input error):

```
1) Calculating the force on the dam
2) Calculating the force for a range of water elevation
3)Exit the program
Please choose a task: 2
The Depth Of The Channel:
0
Width Of The Channel Base:
2
Elevation Of Water Above Channel Bottom:
10
Second Elevation Of Water Above Channel Bottom:
10
Distance From Edge To Bank Of The Channel:
5
Please enter positive values

1) Calculating the force on the dam
2) Calculating the force for a range of water elevation
3)Exit the program
Please choose a task:
```

Test case 1.b: invalid input type (TypeError)

```
1) Calculating the force on the dam
2) Calculating the force for a range of water elevation
3)Exit the program
Please choose a task: 1
The Depth Of The Channel:
2
Width Of The Channel Base:
3
Elevation Of Water Above Channel Bottom:
-4
Distance From Edge To Bank Of The Channel:
-5
Please enter positive values
```

Test case 1.c: Negative value for elevation (LogicError)

```
1) Calculating the force on the dam
2) Calculating the force for a range of water elevation
3)Exit the program
Please choose a task: 6
Please choose one of the option (1,2,3)

1) Calculating the force on the dam
2) Calculating the force for a range of water elevation
3)Exit the program
Please choose a task:
```

Test case 1.d: Depth value of the channel equals zero (MathError)

```
1) Calculating the force on the dam
2) Calculating the force for a range of water elevation
3)Exit the program
Please choose a task: 1
The Depth Of The Channel:
0
Width Of The Channel Base:
4
Elevation Of Water Above Channel Bottom:
3
Distance From Edge To Bank Of The Channel:
5
Please enter positive values
```

Test case 2: Force for the elevation:

```
1) Calculating the force on the dam
2) Calculating the force for a range of water elevation
3)Exit the program
Please choose a task: 1
The Depth Of The Channel:
4
Width Of The Channel Base:
6
Elevation Of Water Above Channel Bottom:
5
Distance From Edge To Bank Of The Channel:
12
Force: 1.50216e+06
```

```
1) Calculating the force on the dam
2) Calculating the force for a range of water elevation
3)Exit the program
```

Test case 3: range of forces for a range of elevations

```
1) Calculating the force on the dam
2) Calculating the force for a range of water elevation
3)Exit the program
Please choose a task: 2
The Depth Of The Channel:
10
Width Of The Channel Base:
4
Elevation Of Water Above Channel Bottom:
1
Second Elevation Of Water Above Channel Bottom:
9
Distance From Edge To Bank Of The Channel:
6
Elevation      :      Force
1              :      19718.1
2              :      80049.6
3              :      184526
4              :      339034
5              :      551812
6              :      833458
7              :      1.19692e+06
8              :      1.6575e+06
9              :      2.23285e+06
```

```
1) Calculating the force on the dam
2) Calculating the force for a range of water elevation
3)Exit the program
```

Test case 4: Exit the program

```
1) Calculating the force on the dam
2) Calculating the force for a range of water elevation
3)Exit the program
Please choose a task: 3
Terminating the Program
```

```
Exit code: 0 (normal program termination)
```

User guide

Determining the force of the water on a dam using the program. You can select from the options to calculate the force for only one elevation or range of forces. The user has to put the values for depth of the channel, width of channel base, elevation of water above channel bottom, distance from edge to the bank of the channel and the program is able to calculate all the following from the parameters that user entered. The user can choose the third option to terminate the program.