**📖 MTH2008** Scientific Computing Logbook

School of Engineering and Physical Sciences, University of Lincoln

Semester A, 2024

*“I confirm that this logbook is entirely my own work and that all references and quotations, from both primary and secondary sources, have been fully identified and properly acknowledged.”* - William Fayers (27378661).

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## **Week 1** – 2024-09-30 to 2024-10-07

**What did you learn in the lab tasks this week?**

In the lab session this week we focused on outputting to a data stream and handling special characters. In order to output to a data stream, I learned we use cout to declare console output and insert data into this with the insertion operator, << - this differs from Python’s print function, but is essentially how it works. This is because C++ is a lower level language, just above assembly code, and is thus more lightweight and efficient, e.g. you don’t need input/output capabilities with all programs, as not all programs need a command-line interface, hence we include the line #include <iostream>to access these stream commands.

Additionally, we explored special characters (\n, \a, \b, \f, \r, and \t), escape sequences (\\, \', \", and \?), and the line terminator (endl). The special characters and escape sequences are similar to those used in Python, but the line terminator was completely new for me. Functionally, it seems to act the same as a newline character, but works by ending the data stream started by cout.

**How well did I learn it?**

I learned everything pretty quickly, making parallels with Python quite often. It’s been really fun learning a completely new, more low-level language and deepening my understanding of programming in general. I did some extra work outside of my lab session, too, which definitely helped me reinforce any new knowledge and understand C++ even quicker.

**How does my solution compare with the official solution?**

There aren’t any official solutions right now, so I’ll write this next week if they get released.

**How can I extend the concepts used in the tasks to form a new project**

In my extra work this week, I’ve extended the concepts used to make Pascal’s triangle by changing the logic to a more loop-based system so that I can use render any number of rows. I also tried an alternative to using the tab characters, setd::setw. Not only this, but I decided to take this number of rows as a user input with std::cin and validated the input, throwing an exception if invalid.

I also researched C++ best practices and styling guidelines, referencing documents like Google Style Guides and Doxygen. The main points are learned from this were: consistent comment style (I opted for /\* and /\*\*), function return rationale (i.e. when to use void), explicitly returning 0 in a main function (to tell the console it ran correctly), docstring placement (before a function, contrasting with Python), and function declaration (placing the opening curly bracket on the same line).

Finally, with the project I already explained, I explored functions, for loops, conditional statements, exception handling, and some basic libraries: cmath, stdexcept, and iomanip.

**Lesson Review Question Answers**

1. Facilitates complex simulations; differs by enabling exploration beyond physical limits.
2. Climate modeling, drug discovery, astrophysics simulations.
3. First computer-assisted proof; raises questions about proof validity.
4. Cost/feasibility issues; safety concerns.
5. From serial to parallel computing; enhances computational power for complex problems.
6. Serial: sequential processing; Parallel: simultaneous processing.
7. Physical limits in miniaturization; heat dissipation, quantum effects.
8. FLOPS: Floating Point Operations Per Second; measures computational performance.
9. Binary: two digits (0, 1); used for electronic circuitry efficiency.
10. Encapsulation, inheritance, polymorphism.

Multiple choice: BCCBCCBBBA

### Basic Use: Using Cout

/\*  
\* PROGRAM: l01-basic\_use-using\_cout.cpp  
\* DESCRIPTION: Use of the cout statment  
\* AUTHOR: William Fayers  
\* DATE: 2024-09-30  
\*/  
  
#include <iostream>  
  
using namespace std;  
  
  
int main()  
{  
 /\* Print a welcome message \*/  
 cout << "Welcome to C++ Programming\n";  
 /\* QUESTION ANSWER (Task 1.5): The first bit of C++ code I've ever written! \*/  
  
 return 0;  
}

### Basic Use: Special Characters

/\*  
\* PROGRAM: l02-basic\_use-special\_characters.cpp  
\* DESCRIPTION: Use of special characters  
\* AUTHOR: William Fayers  
\* DATE: 2024-09-30  
\*/  
  
#include <iostream>  
  
using namespace std;  
  
  
int main()  
{  
 /\* Starting string (for comparison) \*/  
 cout << "Starting string: Welcome to C++ Programming\n" << "---\n";  
  
 /\* Without newline \*/  
 cout << "Without newline: Welcome to C++ Programming" << "---\n";  
 /\*\*  
 \* ANSWER (Task 1.1):  
 \* Removing `/n` causes the output to not start a new line after the string.  
 \*/  
  
 /\* With bell character \*/  
 cout << "With bell character: Welcome to C++ Programming\a" << "---\n";  
 /\* ANSWER (Task 1.3): The bell character `\a` makes a sound in some environments. \*/  
  
 /\* With backspace character \*/  
 cout << "With backspace character: Welcome to C++ Programming\b" << "---\n";  
 /\* ANSWER (Task 1.3): The backspace character \b removes the last character. \*/  
  
 /\* With formfeed character \*/  
 cout << "With formfeed character: Welcome to C++ Programming\f" << "---\n";  
 /\*\*  
 \* ANSWER (Task 1.3):  
 \* The formfeed character \f displays a `♀` character, representing a page break.  
 \*/  
  
 /\* With return character \*/  
 cout << "With return character: Welcome to C++ Programming\r" << "---\n";  
 /\* ANSWER (Task 1.3): The return character \r returns to the start of the line. \*/  
  
 /\* With tab character \*/  
 cout << "With tab character: Welcome to C++ Programming\t" << "---\n";  
 /\* ANSWER (Task 1.3): The tab character \t adds a tab space. \*/  
  
 /\* Escaped characters demonstration \*/  
 cout << "Escaped characters: Is the symbol \\n called \' Newline \' \? \n";  
 /\* ANSWER (Task 1.4): Removing the backslash before the single quote causes a syntax error. \*/  
  
 /\* Line terminator \*/  
 cout << "A rose by any other name would smell as sweet";  
 cout << endl;  
 /\* ANSWER (Task 2.1): The line terminator `endl` starts a new line. \*/  
  
 /\* Line terminator insertion \*/  
 cout << "A rose by any other name would smell as sweet" << endl;  
 /\*\*  
 \* ANSWER (Task 2.2):  
 \* There's no change in output if `endl` is inserted at the end of the string.  
 \*/  
  
 return 0;  
}

### Basic Use: Pascals Triangle

/\*  
\* PROGRAM: l03-basic\_use-pascals\_triangle.cpp  
\* DESCRIPTION: Pracisting cout and special characters  
\* AUTHOR: William Fayers  
\* DATE: 2024-09-30  
\*/  
  
#include <iostream>  
  
using namespace std;  
  
  
int main()  
{  
 /\* Print Pascal's Triangle up to n=5 with cout and the tab character to center the numbers \*/  
 cout << "n\t\t\t\t Pascal's Triangle up to n=5\n";  
 cout << "0\t\t\t\t\t\t1\n";  
 cout << "1\t\t\t\t\t1\t\t1\n";  
 cout << "2\t\t\t\t1\t\t2\t\t1\n";  
 cout << "3\t\t\t1\t\t3\t\t3\t\t1\n";  
 cout << "4\t\t1\t\t4\t\t6\t\t4\t\t1\n";  
 cout << "5\t1\t\t5\t\t10\t\t10\t\t5\t\t1\n";  
  
 cout << "\t\t\t\t Made by William Fayers\n";  
 /\*\*  
 \* ANSWER (Task 3.1):  
 \* I used the tab character, `\t` to center the numbers in the Pascal's Triangle, along with  
 \* `cout` to print the numbers. This ended up with a fairly nice looking Pascal's Triangle:  
 \* ```  
 \* n Pascal's Triangle up to n=5  
 \* 0 1  
 \* 1 1 1  
 \* 2 1 2 1  
 \* 3 1 3 3 1  
 \* 4 1 4 6 4 1  
 \* 5 1 5 10 10 5 1  
 \* Made by William Fayers  
 \* ```  
 \*/  
  
 return 0;  
}

### Pascal Triangle: Extended Project

#include <iostream> /\* For std::cout, std::cin \*/  
#include <cmath> /\* For std::ceil, std::pow \*/  
#include <stdexcept> /\* For std::invalid\_argument \*/  
#include <iomanip> /\* For std::setw \*/  
  
/\*\*  
 \* @file e01-pascal\_triangle-extended\_project.cpp  
 \* @brief Outputs Pascal's triangle to the console.  
 \* @details This program extends the concepts from lab 1 and explores new  
 \* concepts such as error handling, loops, libraries, and functions in C++.  
 \*/  
  
const int MAX\_ROWS = 29;  
const std::string ERROR\_MESSAGE = "Error: rows must be between 0 and "  
 + std::to\_string(MAX\_ROWS) + "!";  
  
/\*\*  
 \* @brief Outputs Pascal's triangle to the console.  
 \*   
 \* @details Calculates Pascal's triangle iteratively using the formula:  
 \* \f[  
 \* C(n, k+1) = C(n, k) \times \frac{n - k}{k + 1}  
 \* \f]  
 \* where \f$C(n, k)\f$ is the coefficient at row \f$n\f$ and column \f$k\f$.  
 \* Ensures the triangle is centered in the console by calculating the maximum  
 \* width of the triangle and the maximum width of the coefficients, using the  
 \* power of 2 to estimate the width of the largest coefficient.  
 \*   
 \* @note Designed to test the use of output streams, loops, error handling, libraries,  
 \* and functions in C++. Extends the concepts from lab 1, exploring new concepts  
 \* like using the `std::setw` function to set the width of the output instead of  
 \* using the tab character.  
 \*   
 \* @param rows The number of rows to output in Pascal's triangle. Must be non-negative  
 \* and less than or equal to MAX\_ROWS.  
 \*  
 \* @throw std::invalid\_argument Throws an error if rows is less than 0 or greater than MAX\_ROWS.  
 \*  
 \* @warning Since the coefficients in Pascal's triangle can grow very large, this  
 \* function may not work as expected for rows greater than 29.  
 \*  
 \* @example  
 \* \code{.cpp}  
 \* output\_pascals\_triangle(4);  
 \* \endcode  
 \*  
 \* Expected Output:  
 \* \code{.plaintext}  
 \* 1  
 \* 1 1  
 \* 1 2 1  
 \* 1 3 3 1  
 \* 1 4 6 4 1  
 \* \endcode  
 \*/  
void output\_pascals\_triangle(int rows) {  
 /\* Throw an error if rows is less than 0 or greater than MAX\_ROWS. \*/  
 if (rows < 0 || rows > MAX\_ROWS) {  
 throw std::invalid\_argument(ERROR\_MESSAGE);  
 }  
  
 /\* Estimate the width of the largest coefficient using the power of 2 \*/  
 int estimated\_max\_coefficient = std::ceil(std::pow(2, rows));  
 int max\_coefficient\_width = std::to\_string(estimated\_max\_coefficient).length() + 1;  
  
 /\* Calculate the maximum width of the triangle. \*/  
 int max\_triangle\_width = max\_coefficient\_width \* (rows + 1);  
  
 /\* Loop through each row in Pascal's triangle. \*/  
 for (int row = 0; row <= rows; row++) {  
 /\* Set the first coefficient to 1 \*/  
 int coefficient = 1;  
  
 /\* Add leading spaces to center the triangle. \*/  
 int leading\_spaces = (max\_triangle\_width - (max\_coefficient\_width \* (row + 1))) / 2;  
 std::cout << std::string(leading\_spaces, ' ');  
  
 /\* Loop through each column in the current row. \*/  
 for (int column = 0; column <= row; column++) {  
 /\* Output the current coefficient. \*/  
 std::cout << std::setw(max\_coefficient\_width) << coefficient;  
  
 /\* Calculate the next coefficient. \*/  
 coefficient = coefficient \* (row - column) / (column + 1);  
 }  
  
 /\* Move to the next row. \*/  
 std::cout << std::endl;  
 }  
}  
  
/\*\*  
 \* @brief Main function to run the program.  
 \*  
 \* @details This function prompts the user for the number of rows to output  
 \* in Pascal's triangle and calls the output\_pascals\_triangle function.  
 \*  
 \* @return Returns 0 to indicate the program has run successfully.  
 \*/  
int main() {  
 /\* Prompt the user for the number of rows to output. \*/  
 std::cout << "Please enter the number of rows you would like to output (0 to "  
 << MAX\_ROWS << "): ";  
 int rows;  
 std::cin >> rows;  
  
 /\* Output Pascal's triangle to the console. \*/  
 try {  
 output\_pascals\_triangle(rows);  
 } catch (const std::invalid\_argument& e) {  
 std::cout << e.what() << std::endl;  
 }  
  
 /\* Output a goodbye message to the user. \*/  
 std::cout << "Made by William Fayers :)" << std::endl;  
  
 /\* Return 0 to indicate the function has run successfully. \*/  
 return 0;  
}