CS12 CH:Floats, Memory, and Input

Data Types, Memory Size, and User Input

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Learning Objectives

- Understand and use the `float` data type for numbers with decimals.
- Differentiate between integer division and floating-point division.
- Define fundamental memory concepts: Bit and Byte.
- Use the `sizeof()` operator to determine the memory footprint of various data types.
- Understand binary (base-2) numbers and how to represent them in C++.
- Use `cin` to get input from a user via the console.

Key Concept: Floating-Point Numbers

- In programming, numbers with decimal parts are called floating-point numbers.
- C++ provides the `float` data type to store these values.
- Declaration and initialization is similar to integers:

Example Syntax

```
float pi = 3.14159;
float price = 0.95;
```

- Floats support standard arithmetic operations: addition, subtraction, multiplication, and division.
- Modulo division (%) is not supported for floating-point types.

Essential Equations: Integer vs. Float Division

The data type of your numbers dictates the type of division C++ performs.

- **Integer Division**: If both operands are integers, the result is an integer. Any fractional part is truncated (cut off).
  -
    $$\frac{5}{4} \to 1$$

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- **Floating-Point Division**: If at least one operand is a float, the result is a float, preserving the decimal.
  - $$\frac{5.0}{4} \to 1.25$$

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  - $$\frac{5.0}{4} \to 1.25$$

This is one of the most common sources of bugs for new programmers!

Code Demo: Division in Action

Demo File: `03_intDivision.cpp` (Interactive - comprehensive demo)
Let's examine how C++ handles different division scenarios.

```
#include <iostream>

using namespace std;

int main()
{
   float a = 5;
   float b = 4;
   float c = 5/4; // Integer division occurs *before* assignment!

   cout << "5/4 = " << 5/4 << endl;         // Integer division
   cout << "c = " << c << endl;             // Result of prior integer division
   cout << "5.0/4 = " << 5.0/4 << endl;     // Floating-point division
   cout << "5/4.0 = " << 5/4.0 << endl;     // Floating-point division
   cout << "a/b = " << a/b << endl;         // Floating-point division (vars)

   return 0;
}
```

Key Concepts: Bits and Bytes

All data in a computer is stored as binary digits, or bits.

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- **Bit**:
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- **Byte**:
  - A group of 8 bits.
  - A common unit for measuring computer memory size.
  - One byte can represent 256 different values (from 0 to 255).

Context: Visualizing a Byte

The terms "bit" and "byte" can be abstract. To make this concrete, the next slide visualizes how 8 individual bits come together to form a single byte, the fundamental unit used to measure the size of data types like `int` and `char`.

Visualization: 8 Bits in 1 Byte

1 Byte

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0

Figure: A byte is a sequence of 8 bits.

Key Concept: The `sizeof()` Operator

Different data types require different amounts of memory to store their values.

- C++ has a built-in operator called `sizeof()` that tells you how much memory (in bytes) a data type or variable occupies.
- This can vary slightly between computer architectures (e.g., 32-bit vs. 64-bit systems).

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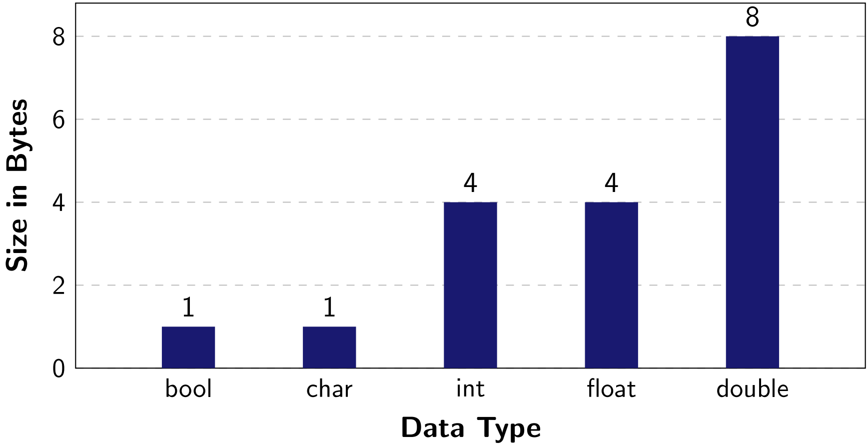
Syntax Examples

```
sizeof(int)      // Returns the size of an integer
sizeof(myAge)    // Returns the size of the variable myAge
```

Context: Visualizing Data Type Sizes

Running a program to see the output of `sizeof()` is useful, but a graph can help us instantly compare the memory footprint of different data types. The next slide shows a bar chart of common data types and their typical sizes in bytes on a 64-bit system. **File:** `03_datatypesSizes.cpp` (Sizes)

Visualization: Typical Data Type Sizes



Key Concept: Binary Numbers

- We typically use the **decimal** (base-10) number system, which has ten digits (0-9).
- Computers use the **binary** (base-2) number system, which has only two digits (0 and 1).
- A number's base indicates how many digits are available.
  - Decimal: $827_{10} = 8 \times 10^2 + 2 \times 10^1 + 7 \times 10^0$
  - Binary: $101_2 = 1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0 = 4 + 0 + 1 = 5_{10}$

Concept: Binary Literals in C++

- You can write numbers in binary directly in your C++ code by using the `0b` prefix.
- When you print the number, C++ will automatically display it in its decimal (base-10) representation.

Code Example:

```cpp
#include <iostream>

int main()
{
   std::cout << "0b1010011 = " << 0b1010011 << std::endl;
   return 0;
}
```

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```cpp
#include <iostream>

int main()
{
    std::cout << "0b1010011 = " << 0b1010011 << std::endl;
    return 0;
}
```

Terminal Output

```
0b1010011 = 83
```

Key Concept: Getting Input with `cin`

- To make programs interactive, we need a way to get input from the user.
- In C++, we use the `cin` object (part of `<iostream>`) for this.
- The extraction operator >> is used to get data from the console and store it in a variable.

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Example: Reading an integer

```
int age; // Declare a variable to store the age

cout << "Please enter your age: "; // Prompt the user
cin >> age; // Read input from the keyboard into 'age'

cout << "You are " << age << " years old." << endl;
```

Why Does Code Formatting Matter?

- **Readability**: Code is read far more often than it is written. Consistent formatting makes it easier for you (and others) to understand what the code is doing.

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- **Maintainability**: It's easier to find bugs and add new features to well-formatted code. Messy code hides problems.
- **Professionalism**: Just like good grammar and spelling in an essay, good formatting is a sign of a careful and professional programmer.

The Golden Rule

Write your code as if the person who has to maintain it is a violent psychopath who knows where you live.

Common C++ Formatting Rules

While style guides vary, most agree on a few key principles:

Bad (Inconsistent)

```
#include <iostream>
int main(){
int x=5;int y=10;
if(x<y){
std::cout<<"x is smaller"<<std::endl;
}
return 0;}
```

Good (Consistent)

```
#include <iostream>

int main() {
    int x = 5;
    int y = 10;

    if (x < y) {
        std::cout << "x is smaller" << std::endl;
    }

    return 0;
}
```

- **Indentation**: Use a consistent number of spaces (e.g., 4) for each level of nesting.
- **Spacing**: Use spaces around operators (‘=‘, ‘+‘, ‘¡‘) to improve readability.
- **Brace Style**: Pick one style for your curly braces ("{}") and stick with it.

The U-P-E-R Problem Solving Method

What is U-P-E-R?

A structured approach to solving programming problems:

- **U - Understand**: Analyze the problem, identify inputs/outputs, and work through examples
- **P - Plan**: Design the logic, identify variables, and create pseudocode
- **E - Execute**: Write the actual code based on your plan
- **R - Review**: Test your code, check for errors, and verify correctness

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Why Use U-P-E-R?

- Breaks complex problems into manageable steps
- Prevents jumping straight to coding without proper planning
- Encourages systematic testing and debugging
- Builds good programming habits for real-world development

I Do: Grade Calculator - Understand

Problem: Write a program that asks for the total possible score on a test, then calculates and displays the minimum score required to earn grades from A to F based on predefined percentages.

U - Understand the Problem

- **Goal:** Calculate grade cutoffs based on a total score.
- **Inputs:** One integer for the total possible score.
- **Outputs:** Three sentences, each stating the required score for a specific grade (A, B, C-).
- **Example:** If input is 100, output for an A (86%) should be 86. If input is 200, output for an A should be 172.

I Do: Grade Calculator - Plan

P - Plan the Logic

- **Variables:**
  - `int totalScore;` to store user input.
  - Use constants for percentages to avoid "magic numbers":
  - `const int GRADE_A = 86;`
  - `const int GRADE_B = 73;`
  - `const int GRADE_C_MINUS = 50;`
- **Steps (Pseudocode):**
  1. Display a prompt asking for the total possible score.
  2. Read the user's input into the `totalScore` variable.
  3. Calculate the cutoff for an 'A': `totalScore * 86 / 100`.
  4. Print the result for 'A'.
  5. Repeat calculation and printing for 'B' (73%) and 'C-' (50%).

I Do: Grade Calculator - Execute & Review

File: 03_grades.cpp (Answer Key) **E - Execute (Write the Code)**

```
#include <iostream>
using namespace std;
// Grade cutoffs
const int GRADE_A = 86;
const int GRADE_B = 73;
const int GRADE_C_MINUS = 50;

int main() {
   int totalScore;
   cout << "Enter total possible score: ";
   cin >> totalScore;

   cout << "For an A, a mark of " << totalScore * GRADE_A / 100 << " is required." << endl;
   cout << "For a B, a mark of " << totalScore * GRADE_B / 100 << " is required." << endl;
   cout << "For a C-, a mark of " << totalScore * GRADE_C_MINUS / 100 << " is required." << endl;
   return 0;
}
```

I Do: Grade Calculator - Execute & Review

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   int totalScore;
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   return 0;
}
```

R - Review and Test

- Compile and run. Does it build without errors?
- Test with example: Input 100. Output is 86, 73, 50. Correct.
- Test with another value: Input 200. Output is 172, 146, 100. Correct.
- What happens if we use floats? The result would be more precise, but here integer truncation is acceptable.

We Do: Arithmetic Sequence - Understand & Plan

Problem (Q5a): Write a code chunk that prompts for n and displays the n^{th} number in the sequence: $11, 15, 19, 23, \ldots$

U - Understand

- **Goal:** Find the value of a term in a sequence.
- **Inputs:** The term number, n.
- **Outputs:** A sentence showing the term and its value.
- **Example:** If $n = 1$, output is 11. If $n = 3$, output is 19.

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P - Plan

- **Variables:** `int n;` for input, `int termValue;` for result.
- **Formula:** The n^{th} term of an arithmetic sequence is $a_n = a + (n - 1)d$.
- Here, first term $a = 11$ and common difference $d = 4$.

We Do: Arithmetic Sequence - Execute & Review

E - Execute the Plan

Based on our plan, how do we translate the formula $a_n = 11 + (n-1) \times 4$ into C++?

```
#include <iostream>
using namespace std;

int main() {
    int n;
    cout << "Enter the term number you want to find: ";
    cin >> n;

    // Calculate the nth term using the formula
    int termValue = _______________________; // What goes here?

    cout << "Term " << n << " is " << termValue << endl;
    return 0;
}
```

We Do: Arithmetic Sequence - Execute & Review

E - Execute the Plan

Based on our plan, how do we translate the formula $a_n = 11 + (n - 1) \times 4$ into C++?

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```

R - Review

You Do: Arithmetic Series Sum

Problem (Q5b): Write a code chunk that prompts for n and displays the *sum* of the first n terms in the series: $2 + 5 + 8 + 11 + \ldots$

Your Task: Use the U-P-E-R Method

1. **Understand**: What are the inputs/outputs? Work out an example for $n = 3$ (sum should be $2 + 5 + 8 = 15$).
2. **Plan**: What variables do you need? What is the formula for the sum of an arithmetic series? ($S_n = \frac{n}{2}(2a + (n-1)d)$).
3. **Execute**: Translate your plan and formula into C++.
4. **Review**: Test your code with your example case. Does it work?

Homework Submission: 03 First C++ Calculations

Instructions

- Submit your completed Jupyter Notebook file named: `firstnameLastname_floats.ipynb`.

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Grading Breakdown

- Content Completion (Parts 1-6): **6 pts**
- Formatting and Structure: **1 pt**

Summary

- The `float` data type is used for numbers with decimal points.
- Division with two integers results in an integer (truncation). If a `float` is involved, the result is a `float`.
- The `sizeof()` operator returns the memory size of a data type in bytes.
- Computers store data using the binary (base-2) system. In C++, you can denote a binary number with the `0b` prefix.
- `cin >> variable;` is the standard way to read user input from the console.
- The U-P-E-R method provides a structured approach to solving programming problems.