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# Overflow and Underflow

This lab serves multiple goals:

* To introduce you to the concept of *overflow* and *underflow*,
* To give an example of the MaxValue and MinValue constants,
* To exemplify the care required when performing mathematical calculations with programs,
* (Optional) To illustrate the String.Format method.

## Overflow

### Warm Up

For a general introduction of overflow, please [read the relevant section](https://princomp.github.io/book.html#overflow). Do execute the code shared in this section:

using System;

class Program
{
 static void Main()
 {
 uint n1,
 n2;

 Console.WriteLine(
 "Enter the requested loan amount for the first person:"
 );
 n1 = uint.Parse(Console.ReadLine());

 Console.WriteLine(
 "Enter the requested loan amount for the second person:"
 );
 n2 = uint.Parse(Console.ReadLine());

 if (n1 + n2 < 10000)
 {
 Console.WriteLine($"Pay ${n1} to the first person");
 Console.WriteLine($"Pay ${n2} to the second person");
 }
 else
 {
 Console.WriteLine(
 "Error: the sum of the loans exceeds the maximum allowance."
 );
 }
 }
}

Make sure you have a general understanding of what overflowing means before proceeding. If you are unsure, reading [about integer overflow on wikipedia](https://www.wikiwand.com/en/Integer_overflow) can help.

We will now enter a surprising world where

* a number can be equal to itself plus one,
* a number plus one can be *less* than the number itself, and
* a number multiplied by two and then divided by two is the same as the number multiplied by two.

Now, [download](https:///princomp.github.io/code/projects/Overflow.zip), execute the “Overflow” solution, and answer the following questions:

* What is the maximum value that can be stored in an int?
* What *should* be the result of adding one to the maximum value that can be stored in an int?
* What is the result actually displayed by C#?

Then, answer the same questions for the float and double datatypes.

### C#’s Checks

We will now study some of the safeguards against overflowing that are implemented in C#. **Note that some of those checks have been deactivated by the** unchecked **command at the beginning of our project. Make sure to complete the following section *outside* of** unchecked**’s scope (i.e., after it).**

1. Enter the following statements in your program:
* int int\_max\_value\_plus\_one\_bis = int.MaxValue + 1;
* You should receive an error message. Reads it and try to understand what C# is warning you against.
1. Isn’t that weird that C# let go
* int int\_max\_value\_ter = int.MaxValue;
int int\_max\_value\_plus\_one\_ter = int\_max\_value\_ter + 1;
* (even outside an unchecked environment, you can try it) not the previous statement? This is because, by default, arithmetic operations on int are “[unchecked](https://learn.microsoft.com/en-us/dotnet/csharp/language-reference/statements/checked-and-unchecked)”. To check it, use
* int int\_max\_value = int.MaxValue;
int int\_max\_value\_plus\_one = checked(int\_max\_value + 1); // Note the "checked(…)".
* What happens when you try to compile and run this program?
1. Note that our program does not give the result of adding one to the maximum value that can be assigned to a decimal. Try to display on the screen the result of adding one to decimal.MaxValue (both inside and outside the unchecked environment).

### Strange Mathematical Properties

Circling back to our prompt in the warm-up section, determine which datatype matches the different overflow behaviors described in the table below, along with the resulting values for each:

| Description | Value(s) | Datatype(s) |
| --- | --- | --- |
| <datatype>.MaxValue == <datatype>.MaxValue + 1 |  |  |
| <datatype>.MaxValue + 1 < <datatype>.MaxValue |  |  |
| <datatype>.MaxValue \* 2 / 2 == <datatype>.MaxValue \* 2 |  |  |

Note that int.MinValue can similarly produce strange mathematical properties of the same kind.

As funny or interesting as that strange behavior may seem, overflow errors actually caused death and millions of dollars of losses repeatedly, as you can read for instance [in this blog post](https://medium.com/%40jollyfish/integer-overflow-underflow-and-floating-point-imprecision-6ba869a99033#73a3).

## Underflow

Most of what we wrote about overflow is also true of *under* flow, and you can read about it [in the lecture notes](https://princomp.github.io/book.html#underflow). In a nutshell, you can witness it by executing a statement such as

Console.WriteLine(0.00000000000000001f \* 0.00000000000000001f);

Which should display 1e-34 but actually displays 9.999999E-35. As you can see, a rounding error took place because C# did not have enough “room” to store all the information. Another interesting example is given by the following loop:

float x = int.MaxValue;
while (x > 0)
{
 Console.Write(x + " ");
 x = x / 2;
}
Console.WriteLine(x);

Note that this loop should *never* exit: no matter how large x is, dividing it by two repeatedly should never make it $0$! After how many iterations would this loop terminate?

## (Optional) String Formatting

As you may have noticed, our program uses the String.Format method to nicely display the information. You can read about this method [in the official documentation](https://learn.microsoft.com/en-us/dotnet/api/system.string.format?view=net-7.0#the-format-method-in-brief).

Compile and execute the following code:

string value = String.Format("|{0,-20:C}|{0,20:C}|{0,10:C}|{0,20:P}|{1}", 126347.89m, "test");
Console.WriteLine(value);

Explain the role of:

* the first digit (either 0 or 1) between the braces,
* the second number (-20, 20, 10, …) between the braces,
* the last character (C, P) between the braces.

Note that the previous statement could have been replaced by

Console.WriteLine("|{0,-20:C}|{0,20:C}|{0,10:C}|{0,20:P}|{1}", 126347.89m, "test");

as Console.WriteLine can process “composite format strings”.