DataVariablesAndOperations

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1 Data, Variables and Operations

1.1 Topics

- data and values
- C++ fundamental data types
- digital units and number systems
- variables and data assignment
- keywords and operators
- order of operations
- operators for numbers and strings
- constants
- type casting

1.2 Data and values

- data and values are the fundamentals to any computer language and program
- a value is one of the fundamental things – like a letter or a number – that a program manipulates
- almost all computer programs use and manipulate some data values

1.3 Literal values and representations

- at a high level, we deal with two types of data values: Numbers and Texts
- numbers can be further divided into two types:
  - Whole number literal values: 109, -234, etc.
  - Floating point literal values: 123.456, -0.3555, etc.
- text is a collection of 1 or more characters (symbols, digits or alpahabets)
  - single character is represent using single quote (')
    - char literal values: 'A', 'a', '%', '1', etc.
  - 2 or more characters are called string
    - represented using double quotes (")
    - string literal values: "CO", "John Doe", "1100", etc.
- programming languages need to represent and use these data correctly

1.4 C++ fundamental types

- there are many fundamental types based on the size of the data program needs to store
  - most fundamental types are numeric types

- see here for all the supported types: https://en.cppreference.com/w/cpp/language/types
- the most common types we use are:

Type	Description	Storage size	Value range
void	an empty set of values; no type	system dependent: 4 or 8 bytes	NA
bool	true or false	1 byte or 8 bits	true or false 1 or 0
char	one ASCII character	1 byte or 8 bits	-2^7 to $2^7 - 1$
unsigned char	one ASCII character	1 byte or 8 bits	0 to $2^8 - 1$
int	+/-ve integers	4 bytes	-2^{31} to $2^{31} - 1$
unsigned int	only positive integers	4 bytes or 32 bits	0 to $2^{32} - 1$
long	+ve and -ve big integers	8 bytes or 64 bits	-2^{63} to $2^{63} - 1$
unsigned long	positive big integers	8 bytes or 64 bits	0 to $2^{64} - 1$
float	single precision floating points	32 bits	7 decimal points
double	double precision floating points	64 bits	15 decimal points

- in C++, there's no fundadamental type available to work with string data
- two common ways to store string data:
  - use C-string or array of characters
  - use basic_string defined in `<string>` library
    - more on basic_string: https://en.cppreference.com/w/cpp/string/basic_string
    - must include `<string>` library and **std** namespace
- we'll dive into string more in depth in **Strings** chapter

1.4.1 sizeof operator

- one may want to know the size of memory allocated for the fundamental types
  - some of these types are system dependent (e.g., long is 32 bit in x86 and 64 bit in x64)
- **sizeof(type)** operator gives size of fundamental types in bytes
- let's check the size of some fundamental types on my 64-bit MacBook Pro laptop

[1]:
```
sizeof(bool)
```

[1]: 1

[2]:
```
sizeof(char)
```

[2]: 1

[3]:
```
sizeof(int)
```

[3]: 4

[4]:
```
sizeof(long)
```

[4]: 8

[5]:
```
sizeof(float)
```

[5]: 4

[6]:
```
sizeof(double)
```

[6]: 8

1.5 Units of digital data

- digital computers use binary number system consisting of two digits (0 and 1)
- every data and code is represented using binary values
  - hence the name binary or byte code for executable programs
  - letter A is encoded as 1000001 (7 binary digits)
- humans use decimal number system with 10 digits (0 to 9)
  - we have ways to represent texts using alphabets for English language e.g.: Hello Bond 707!
  - texts must be encoded into numbers, if we lived in the world that only understood numbers
- the following table shows the various units of digital data

Unit	Equivalent
1 bit (b)	0 or 1
1 byte (B)	8 bits (b)
1 kilobyte (KB)	1,024 B
1 megabyte (MB)	1,024 KB
1 gigabtye (GB)	1,024 MB
1 terabyte (TB)	1,024 GB
1 petabyte (PB)	1,024 TB
…	…

1.6 Number systems

- there are several number systems based on the base digits
  - base is number of unique digits number system uses to represent numbers
- binary (base 2), octal (base 8), decimal (base 10), hexadecimal (base 16), etc.

1.6.1 Decimal number system

- also called Hindu-Arabic number system
- most commonly used number system that uses base 10
  - has 10 digits or numerals to represent numbers: 0..9
  - e.g., 1, 79, 1024, 12345, etc.
- numerals representing numbers have different place values depending on position:
  - ones (10^0), tens(10^1), hundreds(10^2), thousands(10^3), ten thousands(10^4), etc.
  - e.g., $543.21 = (5 \times 10^2) + (4 \times 10^1) + (3 \times 10^0) + (2 \times 10^{-1}) + (1 \times 10^{-2})$

1.7 Number system conversion

- since computers understand only binary, everything (data, code) must be converted into binary
- all characaters (alphabets and symbols) are given decimal codes for electronic communication
  - these codes are called ASCII (American Standard Code for Information Interchange)
  - $A \to 65; Z \to 90; a \to 97; z \to 122, * \to 42$, etc.
  - see ASCII chart: https://en.cppreference.com/w/c/language/ascii

1.7.1 Converting decmial to binary number

- algorithm steps:
  1. repeteadly divide the decimal number by base 2 until the quotient becomes 0
     - note remainder for each division
  2. collect all the remainders in reverse order
     - the first remainder is the last (least significant) digit in binary
- example 1: what is decimal $(10)_{10}$ in binary $(?)_2$?
  - step 1:
    $\frac{10}{2}$ = quotient: 5, remainder: 0 $\frac{5}{2}$ = quotient: 2, remainder: 1 $\frac{2}{2}$ = quotient: 1, remainder: 0 $\frac{1}{2}$ = quotient: 0, remainder: 1
  - step 2:
    - collect remainders from bottom up: 1010
  - so, $(10)_{10} = (1010)_2$
- example 2: what is decimal $(13)_{10}$ in $(?)_2$?
  - step 1:
    $\frac{13}{2}$ = quotient: 6, remainder: 1 $\frac{6}{2}$ = quotient 3, remainder: 0 $\frac{3}{2}$ = quotient: 1, remainder: 1 $\frac{1}{2}$ = quotient: 0, remainder: 1
  - step 2:
    - collect remainders from bottom up: 1101
  - so, $(13)_{10} = (1101)_2$

1.7.2 Converting binary to decimal number

- once the computer does the computation in binary, it needs to convert the results back to decimal number system for humans to understand
- algorithm steps:
  1. multiply each binary digit by its place value in binary
  2. sum all the products
- example 1: what is binary $(1010)_2$ in decimal $(?)_{10}$?
  - step 1:
    - $0 \times 2^0 = 0$
    - $1 \times 2^1 = 2$
    - $0 \times 2^2 = 0$
    - $1 \times 2^3 = 8$
  - step 2:
    - $0 + 2 + 0 + 8 = 10$
  - so, $(1010)_2 = (10)_{10}$
- example 2: what is binary $(1101)_2$ in decimal $(?)_{10}$?
  - step 1:

        * $1 \times 2^0 = 1$
        * $0 \times 2^1 = 0$
        * $1 \times 2^2 = 4$
        * $1 \times 2^3 = 8$
    - step 2:
        * $1 + 0 + 4 + 8 = 13$
    - so, $(1101)_2 = (13)_{10}$
- we got the same decimal vales we started from in previous examples
- food for thought: think how you'd go about writing a program to convert any positive decimal number into binary and vice versa!

1.8 Negative (signed) integers - Two's complement

- most common method of storing negative numbers on computers is a mathematical operation called Two's complement
- Two's complement of an N-bit number is defined as its complement with respect to 2^N
    - the sum of a number and its two's complement is 2^N
- e.g.: for the 3-bit binary number 010_2, the two's complement is 110_2
    - because $010_2 + 110_2 = 1000_2 = 2^3_{10}$
- Two's complement of N-bit number can be found by flipping each bit and adding one to it
- e.g. find two's complement of 010
    - Algorithm steps:
        1. flipped each bit; 0 is flipped to 1 and 1 is flipped to 0

        $010 \rightarrow 101$
        2. add 1 to the flipped binary

```
 101
  +1
-----
 110
```

1.8.1 Example: What is -3 decimal in 8-bit binary representation?

- convert 3_{10} to an 8-bit binary
    - $3_{10} \rightarrow 00000011_2$

1. find Two's complement of 8-bit binary
    - $00000011_2 \rightarrow 11111100_2 + 1 = 11111101_2$
2. Sanity check:
    - $00000011_2 + 11111101_2 = 100000000_2 = 2^8_{10}$

- So, $-3_{10} = 11111101_2$ in an 8-bit representation

1.9 Exercise

1. Convert decimal integer 7 into binary with 16 bits.
2. Convert -7 decimal integer into binary with 16 bits.

1.10 Variables

- programs must load data values into memory to manipulate them

- data may be large and used many times during the program
  - typing the data values literally all the time is not efficient and fun
  - most importantly error prone due to typos
  - you may not even know that values may be if they're read from standard input, files, etc.
- variables are named memory location where data can be stashed for easy access and manipulation
- one can declared and use as many variables as necessary
- C++ is statically and strongly typed programming language
  - variables are tied to their specific data types that must be explictly declared when declaring variables

1.10.1 Variable declaration

- statements that create variables/identifiers to store some data values
- as the name says, value of variables can vary/change over time
- syntax:

```
type varName;
type varNam1, varName2, ...; //declare several variables all of the same type
```

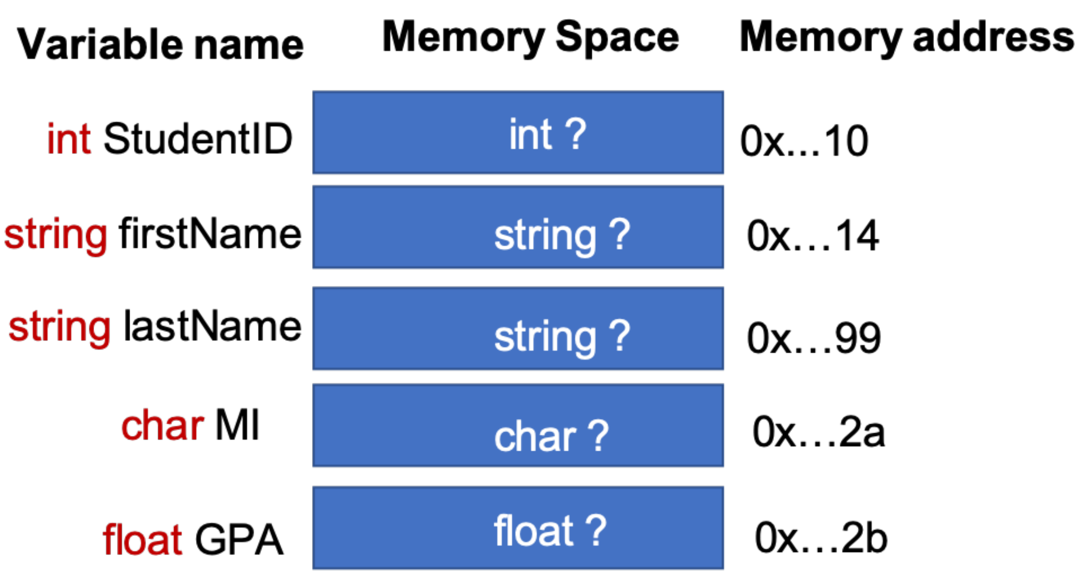

Fig. C++ Variables and Memory

1.10.2 Rules for creating variables

- variable names are case sensitive
- must declare variables before they can be used
- can't define variable with the same name more than once
- can't use keywords as variable names

- data stored must match the type of variable
- variable names can't contain symbols (white spaces, #, &, etc.) except for _ and $ (underscore and dollar)
- variable names can contain digits but can't start with a digit
- variable names can start with only alphabets (lower or upper) and _ symbol

1.10.3 Best practices

- use descriptive and meaningful but concise name
  - one should know quickly what data you're storing
- use lowercase; camelCase or (_ underscore) to combine multiple words

1.10.4 C++ keywords

- keywords are reserved names and words that have specific purpose in C++
  - they can only be used what they're intended for
- e.g., char, int, unsigned, signed, float, double, bool, if, for, while, return, struct, class, operator, try, etc.
- all C++ keywords are listed here: https://en.cppreference.com/w/cpp/keyword

[7]:
```cpp
// examples of variable declaration
bool done;
char middleInitial;
char middleinitial; // hard to read all lowercase name
int temperature;
unsigned int age;
long richest_persons_networth;
float interestRate;
float length;
float width;
double space_shuttle_velocity;
```

[8]:
```cpp
// TODO:
// Declare 10 variables of atleast 5 different types
```

1.10.5 String variables

- declare variables that store string data
  - 1 or more string of characters
- an easy way to use string is by using C++ advanced type defined in `<string>` header file
- must include `<string>` header file or library to use string type
- must also use **std** namespace
- strings are represented using a pair of double quotes ("string")
- more on string type is covered in **Strings** chapter
- the following are some examples of string variables

[9]:
```cpp
// string variables
#include <string>
```

```
using namespace std;

string fullName;
string firstName;
string address1;
string country;
string state_name;
std::string state_code; // :: name resolution operator
```

[10]:
```
// TODO:
// Declare 5 string variables
```

1.11 Assignment operator (=)

- once variables are declared, data can be stored using assignment operator, \$ = \$
- **assignment statements** have the following syntax:

```
varName = value;
```

- since C++ is a strongly typed language, the type of value must match the type of variable
  - strongly typed languages enforces type safety and matching during the compile time

[11]:
```
// assignment examples
done = false;
middleInitial = 'J'; // character is represent using single quote
middleinitial = 'Q';
temperature = 73;
age = 45;
richest_persons_networth = 120000000000; // 120 billion
interestRate = 4.5;
length = 10.5;
width = 99.99f; // number can end with f to represent as float
space_shuttle_velocity = 950.1234567891234567; // 16 decimal points
```

[11]: 950.12346

[12]:
```
// string assignment examples
fullName = "John Doe";
firstName = "John";
address1 = "1100 North Avenue"; // number as string
country = "USA";
state_name = "Colorado";
state_code = "CO";
```

[13]:
```
// TODO: assign different values to variables defined above
```

1.11.1 Variable declartion and initialization

- variables can be declared with initial value at the time of construction
- if you know what value a variable should start with; this saves you typing
- often times its the best practice to initialize variable with default value
- several ways to initialize variables: https://en.cppreference.com/w/cpp/language/initialization
- two common ways:
    1. Copy initialization (using = operator)
    2. Value initialization (using { } curley braces)
        - also called uniform initialization
        - useful in initializing advanced types such as arrays, objects, etc.

[14]:
```
// Copy initialization
float price = 2.99f;
char MI = 'B'; //middle initial
string school_name = "Grand Junction High";
```

[15]:
```
// Value/uniform initialization
char some_letter{'U'};
int some_length{100};
float some_float{200.99};
string some_string = {"Hello World!"}; // can also combine the two!
```

1.11.2 Variable's value can be changed

- variable's value can vary through out the program
    - hence the name variable
- however, type of the value must be same as the type of the variable declared
- C++ is a strongly and statically typed programming language!

[16]:
```
price = 3.99;
price = 1.99;
MI = 'Q';
school_name = "Fruita Monument High";
some_string = "Goodbye, World!";
```

[17]:
```
price = "4.99"; // is this valid?
```

```
input_line_34:2:10: error: assigning to 'float' from

incompatible type 'const char [5]'
 price = "4.99"; // is this valid?
         ^~~~~~



        Interpreter Error:
```

1.11.3 auto type

- if variable is declared and initialized in one statement, you can use **auto** keyword to let compiler determine type of variable based on the value it's initialized with

[18]:
```
auto var1 = 10; // integer
auto var2 = 19.99f; // float
auto var3 = 99.245; // double
auto var4 = '@'; // char
```

[19]:
```
// char * (pointer) type and not string type
auto full_name = "John Doe";
```

[20]:
```
// can automatically declare string type
#include <string>
using namespace std;

auto full_name1 = string("Jake Smith"); // string type!
```

[21]:
```
// use typeid function to find the name of the types
// typeid is defined in typeinfo library
#include <typeinfo>
```

[22]:
```
typeid(full_name1).name()
```

[22]:
```
"NSt3__112basic_stringIcNS_11char_traitsIcEENS_9allocatorIcEEEE"
```

[23]:
```
// should print "i" -> short for integer
// Note: may also print invalid memory address in Jupyter notebook!
typeid(var1).name()
```

[23]:
```
0x7fff67b6373c <invalid memory address>
```

1.11.4 Visualize variables and memory with pythontutor.com

1.12 Operators

- special symbols used to represent simple computations
  - like addition, multiplication, modulo, etc.
- C++ has operators for numbers, characters, and strings
- operators and precedence rule: https://en.cppreference.com/w/cpp/language/operator_precedence
- arithmetic operators: https://en.cppreference.com/w/cpp/language/operator_arithmetic

1.12.1 Unary operators

- takes one operand
- operands are values that operators work on
- there are two unary operators for numeric operands

Operator	Symbol	Syntax	Operation
positive	+	+100	positive 100 (default)
negative	-	-23.45	negative 23.45

1.12.2 Binary operators

- binary operators take two operands (left operator right)
- the following table shows the binary operators for numeric operands

Operator	Symbol	Name	Syntax	Operation
add	+	plus	x + y	add the value of y with the value of x
subtract	-	hyphen	x - y	subtract y from x
multiply	*	asterick	x * y	product of x and y
divide	/	slash	x / y	divide x by y (int division if x and y are both ints)
modulo	%	percent	x % y	remainder when x is divided by y

1.12.3 Adding numbers

- + symbol is used to add literal values or variables

[24]:
```
// adding literal integer values
+1 + (-1)
```

[24]: 0

[25]:
```
// adding literal floating points
99.9 + 0.1
```

[25]: 100.00000

[26]:
```
// adding int variables
int num1, num2, sum;
```

[27]:
```
num1 = 10;
num2 = 5;
sum = num1 + num2;
```

[28]:
```
// let's see the value of sum
sum
```

[28]: 15

[29]:
```
// adding float variables
float n1 = 3.5;
float n2 = 2.5;
float total = n1+n2;
```

[30]:
```
// see total values
total
```

[30]: 6.00000f

1.12.4 Subtracting numbers

- `-` symbol is used to subtract literal numbers or variables

[31]:
```
// subtracting literal integers
10-1
```

[31]: 9

[32]:
```
// subtracting literal floating points
99.99 - 10.99
```

[32]: 89.000000

[33]:
```
// subtracting variables
num1-num2
```

[33]: 5

1.12.5 Multiplying numbers

- `*` asterick symbol is used to multiply literal numbers and variables

[34]:
```
// multiplying literal integers
2*3
```

[34]: 6

[35]:
```
// multiplying literatl floats
2.5 * 2.0
```

[35]: 5.0000000

[36]:
```
// multiplying numeric variables
n1*n2
```

[36]: 8.75000f

1.12.6 Dividing numbers

- `/` symbol is used to divide literal numbers or variables

```
[37]: // dividing literal integers
10/2
```

```
[37]: 5
```

```
[38]: 9/2 // integer division; remainder is discarded
```

```
[38]: 4
```

```
[39]: // dividing literal floats
// if one of the operands is floating point number, C++ performs float division
9.0/2
```

```
[39]: 4.5000000
```

```
[40]: // dividing numeric variables
n1/n2
```

```
[40]: 1.40000f
```

1.12.7 Capturing remainder from a division

- use modulo or remainder (%) operator to find the remainder of literal values or variables
- only works on positive integers

```
[41]: // modulo or remainder operator
5%2 // testing for odd number
```

```
[41]: 1
```

```
[42]: 4%2 // testing for even number
```

```
[42]: 0
```

```
[43]: // can't divide 10 by 11
10%11
```

```
[43]: 10
```

```
[44]: // expressions with variables and literals
// declare some variables
int hour, minute;
```

```
[45]: // assign some values
hour = 11;
minute = 59;
```

[46]:
```
// Number of minutes since midnight
hour * 60 + minute
```

[46]: 719

[47]:
```
// Fraction of the hour that has passed
minute/60
```

[47]: 0

1.12.8 Exercise

- How many hours and minutes are in 121 minutes?

1.12.9 Bitwise operators

- https://www.learncpp.com/cpp-tutorial/38-bitwise-operators/
- bitwise operators work on binary numbers (bits)
  - integers are implicitly converted into binary and then bitwise operations are applied
- bitwise operations are used in lower-level programming such as device drivers, low-level graphics, communications protocol packet assembly, encoding and decoding data, encryption technologies, etc.
- a lot of integer arithmetic computations can be carried our much more efficiently using bitwise operations

Operator	Symbol	Symbol Name	Syntax	Operation
bitwise left shift	«	left angular bracket	x « y	all bits in x shifted left y bits; multiplication by 2^y
bitwise right shift	»	right angular bracket	x » y	all bits in x shifted right y bits; division by 2^y
bitwise NOT	~	tilde	~x	all bits in x flipped
bitwise AND	&	ampersand	x & y	each bit in x AND each bit in y
bitwise OR	|	pipe	x | y	each bit in x OR each bit in y

Operator	Symbol	Symbol Name	Syntax	Operation
bitwise XOR	^	caret	x ^ y	each bit in x XOR each bit in y

1.12.10 Table for bitwise operations

x	y	x & y
1	1	1
1	0	0
0	1	0
0	0	0

& - bitwise AND

x	y	x | y
1	1	1
1	0	1
0	1	1
0	0	0

| - bitwise OR

x	~x
1	0
0	1

~ - bitwise NOT

x	y	x ^ y
1	1	0
1	0	1
0	1	1
0	0	0

^ - bitwise XOR

bitwise left shift examples

[48]:
```
// convert 1 decimal to binary and shift left by 4 bits
1 << 4 // same as 1*2*2*2*2; result is in decimal
```

[48]:
```
16
```

Explanation

- Note: in the given example, binary uses 32-bit to represent decmial
- $1_{10} = 00000000000000000000000000000001_2$
- $1 << 4 = 000000000000000000000000000010000 = 2^4 = 16_{10}$

[49]:
```
3 << 4 // same as 3*2*2*2*2 or 3*2^4
```

[49]:
```
48
```

Explanation

- $3_{10} = 00000000000000000000000000000011_2$
- $3 << 4 = 00000000000000000000000000110000_2 = 2^5 + 2^4 = 32 + 16 = 48_{10}$

Bitwise right shit examples

[50]:
```
1024 >> 10 // same as 1024/2/2/2/2/2/2/2/2/2/2
```

[50]:
```
1
```

Explanation

- $1024_{10} = 00000000000000000000010000000000_2$
- $1024 >> 10 = 00000000000000000000000000000001 = 2^0 = 1_{10}$

Bitwise NOT examples

[51]:
```
~0 // result shown is in decimal!
```

[51]:
```
-1
```

[52]:
```
~1 // Note: 1 in binary using 32-bit width (31 0s and 1) 00000....1
// result shown is in decimal
```

[52]:
```
-2
```

Explanation

- $0_{10} = 00000000000000000000000000000000_2$
- $1_{10} = 00000000000000000000000000000001_2$
- $-1_{10} = 11111111111111111111111111111111_2$
- $2_{10} = 00000000000000000000000000000010_2$

- $-2_{10} = 11111111111111111111111111111110_2$
- Note: -ve numbers are stored in Two's complement
  - 2's complement is calculated by flipping each bit and adding 1 to the binary of positive integer

Bitwise AND examples

[53]:
```
1 & 1
```
[53]: 1

[54]:
```
1 & 0
```
[54]: 0

[55]:
```
0 & 1
```
[55]: 0

[56]:
```
0 & 0
```
[56]: 0

Bitwise OR examples

[57]:
```
1 | 1
```
[57]: 1

[58]:
```
1 | 0
```
[58]: 1

[59]:
```
0 | 1
```
[59]: 1

[60]:
```
0 | 0
```
[60]: 0

Bitwise XOR examples

[61]:
```
1 ^ 1
```
[61]: 0

[62]:
```
1 ^ 0
```

[62]: 1

[63]:
```
0 ^ 1
```

[63]: 1

[64]:
```
0 ^ 0
```

[64]: 0

1.13 Order of operations

- expressions may have more than one operators
- the order of evaluation depends on the rules of precedence

1.13.1 PEMDAS

- acronym for order of operations from highest to lowest
  1. **P** : Parenthesis
  - **E** : Exponentiation
  - **M** : Multiplication
  - **D** : Division
  - **A** : Addition
  - **S** : Subtraction
- when in doubt, use parenthesis!

[65]:
```
// computation is similar to what we know from Elementary Math
2+3*4/2-2
```

[65]: 6

[66]:
```
// same as
(2+((3*4)/2))-2
```

[66]: 6

[67]:
```
(2+3)*4/(2-1) // Note: must use * to multiply after ( )
```

[67]: 20

[68]:
```
// typical mistake
(2+3)4/(2-1) // error
```

```
input_line_129:2:7: error: expected ';' after

expression
 (2+3)4/(2-1) // error
```

```
^

;
```

```
Interpreter Error:
```

1.14 Operators for characters

- mathematical operators also work on characters
- characters' ASCII values are used in computations
- C++, when safe, converts from one type to another; called type **coercion**
  - characters are converted into their corresponding integer ASCII values
  - **coercion** is safe when data is not lost, e.g. converting int to float

[69]:
```
'a'+1 // a -> 97
```

[69]: 98

[70]:
```
'A'-1 // A -> 65
```

[70]: 64

[71]:
```
'A'*10
```

[71]: 650

[72]:
```
'A'/10
```

[72]: 6

[73]:
```
'A'+'A'
```

[73]: 130

1.15 Operators for strings

- certain operators are defined or overloaded for string types
  - more on user defined advanced types and operator overloading later
- + : concatenates or joins two strings giving a new longer string

[74]:
```
// variables can be declared and intitialized at the same time
#include <iostream>
#include <string>
using namespace std;

string fName = "John";
```

```
string lName = "Smith";
string space = " ";
string fullName = fName + space + lName;
```

[75]:
```
fullName
```

[75]: "John Smith"

1.16 Constants

- constants are named values that remain unchanged through out the program
- useful for declaring values that are fixed
  - e.g. value of π, earth's gravity, unit conversions, etc.
- two ways to define constants in C++
  1. use **const** keyword infront of an identifier
     - syntax:

     `const type identifier = value;`
  2. use **#define** preprocessor directive
     - syntax:

     `#define identifier value`
     - after an identifier has been defined with a value, preprocessor replaces each occurances of PI with value

[76]:
```
const double pi = 22/7.0; // evaluate 22/7.0 and use it as the const value for␣
↪pi
const float earth_gravity = 9.8; // m/s^2 unit
```

[77]:
```
// let's see the value of constant pi
pi
```

[77]: 3.1428571

[78]:
```
// try to assign different value to the constant pi
pi = 3.141592653589793238;
```

```
input_line_148:3:4: error: cannot assign to variable

'pi' with const-qualified type 'const double'
pi = 3.141592653589793238;
~~ ^

input_line_145:2:15: note: variable 'pi' declared const
here
 const double pi = 22/7.0; // evaluate 22/7.0 and use it as the const value for
pi
 ~~~~~~~~~~~~~^~~~~~~~~~
```

```
Interpreter Error:
```

[79]:
```
// let's use constants
double radius = 10.5;
double area_of_circle = pi*radius*radius;
```

[80]:
```
// value of area of circle
area_of_circle
```

[80]: 346.50000

[81]:
```
// preprocessor directive to declare named constant
#define PI 3.141592653589793238
```

[82]:
```
PI*radius*radius
```

[82]: 346.36059

1.16.1 floating point operation accuracy

- floating point calculations may not be always 100% accurate
- you have to choose the accuracy upto certain decimal points to accept the results as correct
- google area of circle
  - use same radius 10.5 and compare the results provided above

1.17 Type casting

- data values need to be converted from one type to another to get correct results
- explictly converting one type into another is called **type casting**
- implict conversion is called **coercion**
- not all values can be converted from one type to another!

1.17.1 Converting numeric values to string type

- use `to_string(value)` function to convert `value` to `string`
- must include `<string>` header and **std** namespace

[83]:
```
#include <string>
using namespace std;

string str_val = to_string(99); // 99 is casted "99" and the value is assigned
 ↪to str_val
```

[84]:
```
str_val
```

[84]: "99"

[85]:
```
// typeinfo library can be used to know the name of data types
#include <typeinfo>
```

[86]:
```
// typeid operator is defined in typeinfo library
typeid(str_val).name()
```

[86]: "NSt3__112basic_stringIcNS_11char_traitsIcEENS_9allocatorIcEEEE"

[87]:
```
int whole_num = 1234;
string str_val1 = to_string(whole_num);
```

[88]:
```
str_val1
```

[88]: "1234"

[89]:
```
float float_num = 129.99f;
string str_num1 = to_string(float_num);
```

[90]:
```
str_num1
```

[90]: "129.990005"

[91]:
```
string str_val2 = to_string('A'); // uses ASCII value
```

[92]:
```
str_val2
```

[92]: "65"

1.17.2 Converting string values to numeric types

- certain values can be converted into numeric types such as int, float, double, etc.
- `<cstdlib>` provides some functions for us to convert c-string to numeric data
- more on `<cstdlib>`: http://www.cplusplus.com/reference/cstdlib
- `atoi("value")` converts string `value` to integer
  - converts all leading consecutive digits as integer
- `atof("value")` converts string `value` to double
- must include `<cstdlib>` library to use its functions
  - converts all leading consecutive digits and period as floating point number

[93]:
```
#include <cstdlib> //atoi and atof
```

[94]:
```
// converting string to integers
atoi("120")
```

[94]: 120

[95]:
```
atoi("43543 alphabets")
```

[95]: 43543

[96]:
```
atoi("text 123")
```

[96]: 0

[97]:
```
atof("23.55")
```

[97]: 23.550000

[98]:
```
atof("132.68 text")
```

[98]: 132.68000

[99]:
```
atof("text 4546.454")
```

[99]: 0.0000000

1.17.3 Converting C++ strings into numeric types

- http://www.cplusplus.com/reference/string/
- **<string>** library provides many functions to convert std::string into numeric types
- **stoi( )** - converts std:string type to integer
- **stof( )** - converts std::string type to float
- **stol( )** - converts std::string type to long int
- **stoul( )** - converts std::string to unsigned long integer

[100]:
```
#include <string>
using namespace std;
```

[101]:
```
string int_num = "99";
string float_num = "100.99";
```

[102]:
```
// typecast string int and string float to corresponding numeric types
// do + operation on numeric types
float result = stoi(int_num)+stof(float_num);
```

[103]:
```
result
```

[103]: 199.990f

1.17.4 Type casting among numeric types

- at times, you may need to convert integers to floating points and vice versa
- use **int(value)** to convert float to int

- use **float(value)** to convert int or double to float
- use **double(value)** to convert int or float to double
- don't need to include any library to use these built-in functions

[104]:
```
int(10.99) // convert double to int; discard decimal points or round down
```

[104]: 10

[105]:
```
int(345.567f) // discard decimal points or round down
```

[105]: 345

[106]:
```
float(19)
```

[106]: 19.0000f

[107]:
```
double(3.33f) // convert float to double
```

[107]: 3.3299999

[108]:
```
double(3)
```

[108]: 3.0000000

1.17.5 Type casting between char and int

- use `char(intValue)` to convert ASCII `int` to `char`
- use `int(charValue)` to convert `char` to ASCII `int`

[109]:
```
char(65) // ASCII code to char
```

[109]: 'A'

[110]:
```
int('A') // char to ASCII code
```

[110]: 65

1.18 Labs

1. Variables Lab
    - write a C++ program that produces the following output on console
    - use the partial solution provided in `labs/variables/main.cpp`
    - observe and note how the special symbols such as single quote, double quotes and black slashes
    - run the program as it is using the provided make file in the stdio folder
    - complete the rest of the ASCII Art by fixing all the FIXMEs
    - write #FIXED next to each FIXME

```
   |\_/|        ******************************     (\_/)
  / @ @ \       *      ASCII Art             *    (='.'=)
 ( > 0 < )      *      Author: <Your Name>    *  ( " )_( " )
   >>x<<        *      CS Foundation Course   *
   / O \        ******************************
```

1.19 Exercises

1. Declare some variables required to store information about a student for a university banner system. Assign some values to those variables.
   - see sample answer here `exercises/variables/exercise1`
2. Declare some variables required to store information about an employee at a university. Assign some values to those variables.
3. Declare some variables required to store information about a mechandise for an inventory management system of a store. Assign some values to those variables.
4. Declare some variables required to store infomration about a rectangular shape. Calculate area and perimeter of a rectangle. Assign some values to those variables.
5. Declare variables required to store information about a circle to calculate its area and perimeter. Assign some values to those variables. Calculate area and perimeter.
6. Declare some variables required to store information about a hotel room for booking management system.
7. Declare some variables required to store length of sides of a triangle. Calculate area using Herons' formula.
   - Search for Heron's formula, if you're not sure what it is.
8. Using pencil and paper or Jupyter Notebook, write your full name in binary.

- e.g., Ram Basnet in Binary is:
- 01010010 01100001 01101101 00100000 01000010 01100001 01110011 01101110 01100101 01110100

1.20 Summary

- this notebook discussed data and C++ fundamental data types
- variables are named memory location that store data values
- C++ variables are static and strongly typed
- looked into C++ operators for various data types
- learned about order of operations, PEMDAS
- learned that constants are used to store values that should not be changed in program
- exercises and sample solutions

[ ]: