Chapter 3: Arithmetic,Variables, Input, Constants, & Library Functions

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Objectives

- Use data of types **int** and **double** in arithmetic expressions.
- Identify mixed-mode expressions and convert data to different types when necessary.
- Understand the utilization of memory for storing data.
- Declare, initialize, and use variables in expressions, assignment statements, and output statements.

Objectives cont.

- Use the standard input stream and its operator to get data for a program.
- Declare and use string variables.
- Know how character data are represented in computer memory.
- Use constants, library functions, and member functions in programs.

Integer Arithmetic

+	Addition
-	Subtraction
*	Multiplication
/	Quotient (Integer Division)
%	Remainder (Modulus)

$$\begin{array}{r} \mathit{Quotient} \\ \mathit{Divisor}\overline{\big)\,\mathit{Dividend}} \end{array} + \frac{\mathrm{Re}\,\mathit{mainder}}{\mathit{Divisor}}$$

Integer Order Of Operations

- Expressions within parentheses
  - nested parentheses: from inside out
- * (multiplication), % (modulus), / (division)
  - from left to right
- + (addition), - (subtraction)
  - from left to right

Integer Arithmetic (Examples)

(3-4)*5 =	-5
3 * (-2) =	-6
17 / 3 =	5
17 % 3 =	2
17 / (-3) =	-5
-17 % 7 =	-3
-42+50%17=	-26

Integers

- Stored as binary numbers inside the computer.
- Integers produce exact answers
- Int_Min and Int_Max

  -2,147,483,648 and 2,147,483,647
- Integer Overflow
  - a number is too large or too small to store
  - no error message
  - unpredictable value

Real Number Arithmetic

- Type double:

+	Addition
-	Subtraction
*	Multiplication
/	Division

Real Number
Order Of Operations

- Expressions within parentheses
  - nested parentheses: from inside out
- * (multiplication), / (division)
  - from left to right
- + (addition), - (subtraction)
  - from left to right

Real Number Arithmetic (Examples)

2.0 * (1.2 - 4.3) = -6.2

2.0 * 1.2 - 4.3 = -1.9

-12.6 / (3.0 + 3.0) = -2.1

3.1 * 2.0 = 6.2

-12.6 / 3.0 + 3.0 = -1.2

Real Numbers

- Bring Calculators to check your math
- Are stored using binary numbers
- Round Off Error
  - 1.0/3.0 = 0.3333……….
- Underflow
  - very small numbers may be stored as zero

0.0000000000000000000123 stored as zero

Real Numbers

- Representational errors
  - precision of data reduced because of the order in which operations are performed
  - (-45.5 + 45.6) + 0.215 = 0.315
    - 0.1 + 0.215 = 0.315
  - -45.5 + (45.6 + 0.215) = 0.3
    - if three digits of accuracy are the computers limit
    - 45.6 + 0.215= 45.815 or 45.8
    - -45.5 + 45.8 = 0.3

Real Numbers

- Cancellation Error
  - lost data due to differences in the precision of operands
  - 2 + 0.0005 = 2.0005 but only 2.00 if 3 digits of precision
  - If possible, add all small numbers before adding to a larger number
  - Real Overflow: trying to store very large numbers

Real Number Limits

- DBL_MIN

  2.22507e-308

- DBL_MAX
  - 1.79769e+308
- Number of digits in double: 15

Variables

- Memory Location
  - storage cell that can be accessed by address
- Variable
  - memory location, referenced by identifier, whose value can be changed during a program
- Constant
  - Symbol whose value can't be changed in the body of the program

Assignment Statements

- A Method of putting values into memory locations
  - <variable name> = <value>;
  - <variable name> = <expression>;
- Assignment is made from right to left
- Constants can't be on left side of statement
- Expression is a Constant or variable or combination thereof

Assignment Statements

- Values on right side not normally changed
- variable and expression must be of compatible data types (more later)
- Previous value of variable discarded to make room for the new value
- For now, char, int, and double are compatible with each other

Assignment Examples

- score1 = 72.3;
- score2 = 89.4;
- score3 = 95.6;
- average = (score1 + score2 + score3) / 3.0
  - why not divide by 3 instead of 3.0?

Compound Assignments

- “Short hand” notation for frequently used assignments (We will not use these for readability of our programs.)

Short hand	Longer form
x += y	x = x + y
x -= y	x = x - y
x *= y	x = x * y
x /= y	x = x / y
x %= y	x = x % y

Sample Program

Here is a program that prints data about the cost of three textbooks and calculates the average price of the books:

BooksDev.cpp

Software Engineering

- Self-documenting code
  - Code that is written using descriptive identifiers
- Always use descriptive variable names and constant names
  - Remember: don’t abbreviate identifier names when possible.

Input

- cin (pronounced see-in)
  - gets data from keyboard, the standard input stream
  - extractor operator >>
    - obtain input from standard input stream and direct it to a variable (extract from stream to variable)
  - inserter operator <<
    - insert data into standard output stream
  - EGG ILL
    - Extractor Greater Greater, Inserter Less Less

Input

- Data read in from keyboard must match the type of variable used to store data
- Interactive Input
  - enter values from keyboard while the program is running
  - cin causes the program to stop and wait for the user to enter data from the keyboard
  - prompt the user for the data (user friendly)

Input: Sample Programs

No prompt for any of the data values:

INPUTDev.cpp

One prompt for each data value (preferred)

TRIPLESDev.cpp

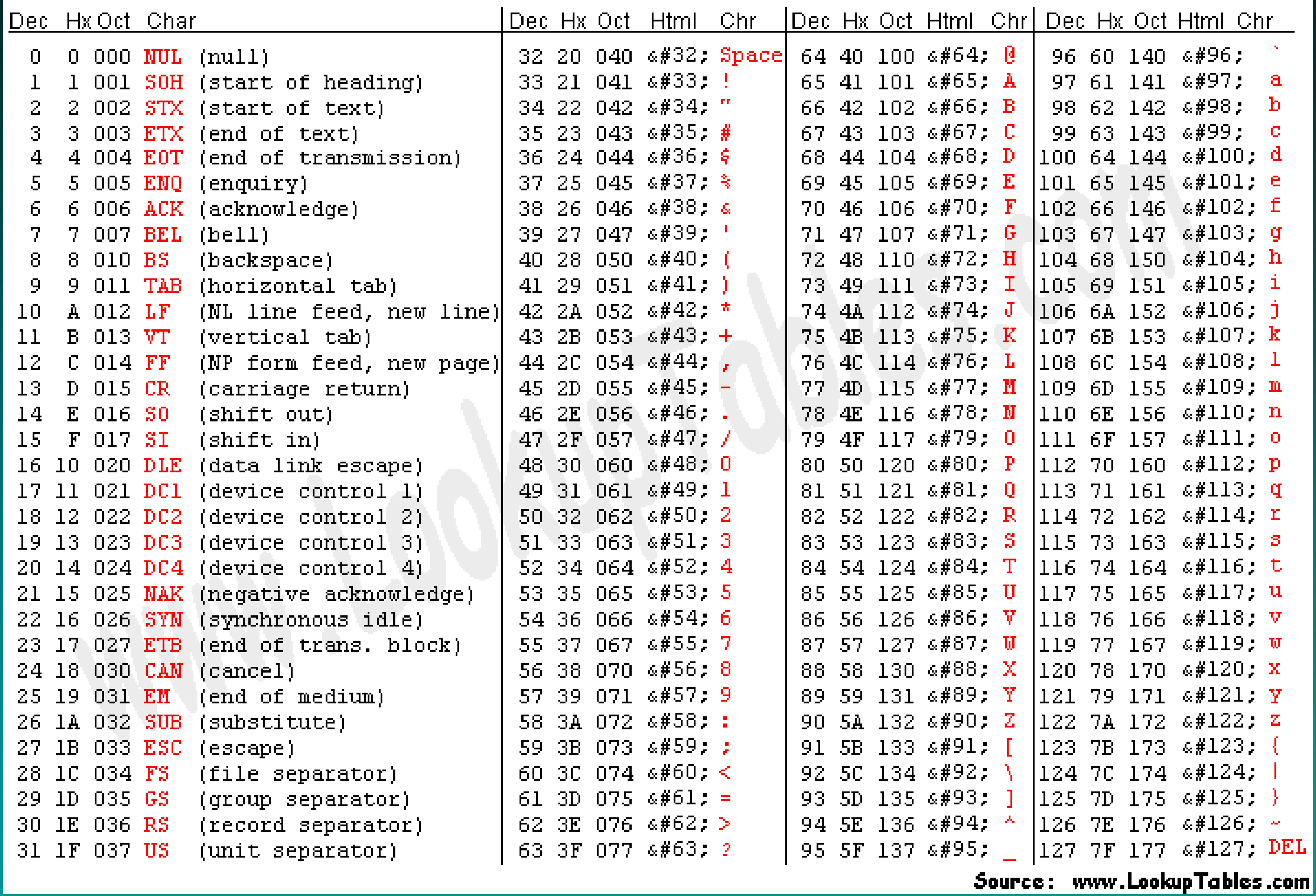
Character Data

- Type char
  - each char is associated with an integer value
- Collating sequence
  - order of character data used by the computer
- Character set
  - the character list available
  - ASCII (American Standard Code for Information Interchange) on our systems: page 85

ASCII Code

	0	1	2	3	4	5	6	7	8	9
0	NUL	SOH	STX	ETX	EOT	ENQ	ACK	BEL	BS	HT
1	LF	VT	FF	CR	SO	SI	DLE	DC1	DC2	DC3
2	DC4	NAK	SYN	ETB	CAN	EM	SUB	ESC	FS	GS
3	RS	US	SP	!	"	#	$	%	&	`
4	(	)	*	+	,	-	.	/	0	1
5	2	3	4	5	6	7	8	9	:	;
6	<	=	>	?	@	A	B	C	D	E
7	F	G	H	I	J	K	L	M	N	O
8	P	Q	R	S	T	U	V	W	X	Y
9	Z	[	\	]	^	_	'	a	b	c
10	d	e	f	g	h	i	j	k	l	m
11	n	o	p	q	r	s	t	u	v	w
12	x	y	z	{	|	}	~	DEL		

Full ASCII Code Chart



Dec	Hx	Oct	Char	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr
0	0	000	NUL (null)	32	20	040	&#32;	Space	64	40	100	&#64;	@	96	60	140	&#96;	`
1	1	001	SOH (start of heading)	33	21	041	&#33;	!	65	41	101	&#65;	A	97	61	141	&#97;	a
2	2	002	STX (start of text)	34	22	042	&#34;	"	66	42	102	&#66;	B	98	62	142	&#98;	b
3	3	003	ETX (end of text)	35	23	043	&#35;	#	67	43	103	&#67;	C	99	63	143	&#99;	c
4	4	004	EOT (end of transmission)	36	24	044	&#36;	$	68	44	104	&#68;	D	100	64	144	&#100;	d
5	5	005	ENQ (enquiry)	37	25	045	&#37;	%	69	45	105	&#69;	E	101	65	145	&#101;	e
6	6	006	ACK (acknowledge)	38	26	046	&#38;	&	70	46	106	&#70;	F	102	66	146	&#102;	f
7	7	007	BEL (bell)	39	27	047	&#39;	'	71	47	107	&#71;	G	103	67	147	&#103;	g
8	8	010	BS (backspace)	40	28	050	&#40;	(	72	48	110	&#72;	H	104	68	150	&#104;	h
9	9	011	TAB (horizontal tab)	41	29	051	&#41;	)	73	49	111	&#73;	I	105	69	151	&#105;	i
10	A	012	LF (NL line feed, new line)	42	2A	052	&#42;	*	74	4A	112	&#74;	J	106	6A	152	&#106;	j
11	B	013	VT (vertical tab)	43	2B	053	&#43;	+	75	4B	113	&#75;	K	107	6B	153	&#107;	k
12	C	014	FF (NP form feed, new page)	44	2C	054	&#44;	,	76	4C	114	&#76;	L	108	6C	154	&#108;	l
13	D	015	CR (carriage return)	45	2D	055	&#45;	-	77	4D	115	&#77;	M	109	6D	155	&#109;	m
14	E	016	SO (shift out)	46	2E	056	&#46;	.	78	4E	116	&#78;	N	110	6E	156	&#110;	n
15	F	017	SI (shift in)	47	2F	057	&#47;	/	79	4F	117	&#79;	O	111	6F	157	&#111;	o
16	10	020	DLE (data link escape)	48	30	060	&#48;	0	80	50	120	&#80;	P	112	70	160	&#112;	p
17	11	021	DC1 (device control 1)	49	31	061	&#49;	1	81	51	121	&#81;	Q	113	71	161	&#113;	q
18	12	022	DC2 (device control 2)	50	32	062	&#50;	2	82	52	122	&#82;	R	114	72	162	&#114;	r
19	13	023	DC3 (device control 3)	51	33	063	&#51;	3	83	53	123	&#83;	S	115	73	163	&#115;	s
20	14	024	DC4 (device control 4)	52	34	064	&#52;	4	84	54	124	&#84;	T	116	74	164	&#116;	t
21	15	025	NAK (negative acknowledge)	53	35	065	&#53;	5	85	55	125	&#85;	U	117	75	165	&#117;	u
22	16	026	SYN (synchronous idle)	54	36	066	&#54;	6	86	56	126	&#86;	V	118	76	166	&#118;	v
23	17	027	ETB (end of trans. block)	55	37	067	&#55;	7	87	57	127	&#87;	W	119	77	167	&#119;	w
24	18	030	CAN (cancel)	56	38	070	&#56;	8	88	58	130	&#88;	X	120	78	170	&#120;	x
25	19	031	EM (end of medium)	57	39	071	&#57;	9	89	59	131	&#89;	Y	121	79	171	&#121;	y
26	1A	032	SUB (substitute)	58	3A	072	&#58;	:	90	5A	132	&#90;	Z	122	7A	172	&#122;	z
27	1B	033	ESC (escape)	59	3B	073	&#59;	;	91	5B	133	&#91;	[	123	7B	173	&#123;	{
28	1C	034	FS (file separator)	60	3C	074	&#60;	<	92	5C	134	&#92;	\	124	7C	174	&#124;	|
29	1D	035	GS (group separator)	61	3D	075	&#61;	=	93	5D	135	&#93;	]	125	7D	175	&#125;	}
30	1E	036	RS (record separator)	62	3E	076	&#62;	>	94	5E	136	&#94;	^	126	7E	176	&#126;	~
31	1F	037	US (unit separator)	63	3F	077	&#63;	?	95	5F	137	&#95;	_	127	7F	177	&#127;	DEL

Source: www.LookupTables.com

Constants

- Symbolic constant: PI
- Literal constant: 3.14
- Constant declaration section
  - after Preprocessor Directives
  - after “**using namespace std;**”
  - before type definition section, program heading, and the int main( ) function.
  - Literal constant is assigned to symbolic constant
    - const double PI = 3.14;
- Style for constants is ALL_CAPS

Rationale for using Constants

- Programs are easier to read
- Easier to change values that are currently fixed but subject to change in the future
    - i.e. STATE_TAX_RATE
    - change one line, rather than searching every line
- Programs more reliable
    - fewer chances for typos
    - compiler will "catch" named constant typos

Library Constants

- What are the ranges from minimum to maximum for the types char, int, double, etc.?
  - # include <limits>;
  - # include <cfloat>;
- Varies by computer system
- Here is a test program to display the values

SIZESDev.cpp

String Variables

- string data type
- Used to store a sequence of characters
- string name;   //not initialized
- string fullName = “”; //initialized to empty string
- string myName = “Mr. Clausen”;

String Input with >>

- The >> operator ignores leading whitespace
  - space, tab, or carriage return
- Then reads nonblank characters
  - until next whitespace character
  - user is allowed to use backspace or delete
    - until next whitespace character
- Upon return or whitespace string is stored
- >> Can't be used for strings with spaces.

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String Input with getline

- Getline function
  - reads characters, tab, space into string variable
  - until newline (‘/n’) char
  - the newline char is not stored in the string variable
  - getline (<input stream>, <string variable>);
    - **getline (cin, name);**
  - doesn’t ignore leading whitespace characters

Pg88ex2

Using cin>> before getline

- >> reads and stores up to newline
- getline reads newline as first char of line
- and quits reading at newline
- any string variables in getline are empty

Pg89ex3v2

Solutions for >> before getline

- Use getline (cin, consume_newline) to consume newline character
- This is the required method, for example:

P89ex5

More on strings

- Length function returns number of characters in a string
  - <string variable>.length()
    - cout <<“Length of “ <<word <<” = “ <<word.length( ) <<endl;
    - length_of_word = word.length( );
- No memory is allocated when a string variable is declared, length is zero characters.
- Empty string is “”
  - length is zero characters.

string Functions

string Member Function	What It Does	Example Use

int length()	Returns the number of characters in the string.	string word=””;
		int word_length =0;
		word = "Hello there";
		word_length = word.length();
		cout<<word_length;
		// Displays 11

int find(<a string>)	Returns the starting position of the first occurrence of a string or -1 if the string does not exist.	string word=””;
		int location =0;
		word = "Hello there";
		location = word.find("there");
		cout << location;
		// Displays 6

int find(<a character>)	Returns the starting position of the first occurrence of a character or -1 if the character does not exist.	string word=””;
		int location =0;
		word = "Hello there";
		location = word.find('H');
		cout << location;
		// Displays 0

string substr(<position>, <length>)	Returns a substring of **length** characters starting at **position**	string word=””;
		string word2=””;
		word = "Hello there";
		word2 = word.substr(3, 2);
		cout << word2;
		// Displays "lo"

String Concatenation

- Concatenation
  - an operation to append the contents of one data structure after the contents of another data structure
  - + means concatenate for strings
  - + means addition for numbers

Concatenation Example 1

- To create a new string

```
string first, second, third;

first = “Hi”;
second = “ there”;
third = first + second;
cout<<third;
```

Concatenation Example 2

- To append a character to the end of a string

```
string singular;   //error in textbook, this is correct

singular = “fish”;
cout << singular + “es”;
```

Library Functions

- Different versions of C+ + have different library functions available.
- **#include <cmath>**
- Form for using a function:
  - <function name> (<argument list>);
  - an argument is a expression, variable or constant
- A function is invoked or called when used in a statement
    - answer = pow(3,4);
    - result = pow(base, exponent);

Library Functions

- List of Library Functions in Appendix 2
- Two to know for now…
  - sqrt   square root
  - pow   raise a base to a power
  - Examples:
    - sqrt (25)   sqrt (25.0)
    - pow(2,4)   pow(-3,5)   pow(2.0,4)
    - square_root = sqrt (number);
    - answer = pow(base, exponent);

Sample Library Functions

Function Declaration	Action of Function
`double fmod(double x, double y);`	returns floating-point remainder of x / y
`double log(double x);`	returns natural logarithm of x
`double pow(double x, double y);`	returns x raised to power of y
`double sqrt(double x);`	returns square root of x
`double cos(double x);`	returns cosine of x

Expression	Value
`pow(2, 4)`	16
`pow(2.0, 4)`	16.0
`pow(-3, 2)`	9
`fmod(5.3, 2.1)`	1.1
`sqrt(25.0)`	5.0
`sqrt(25)`	5
`sqrt(0.0)`	0.0
`sqrt(-2.0)`	Not permissible

Member Functions

- Some library functions are associated with a data type called classes.
- Class: a description of the attributes and behavior of a set of computational objects.
- Member function: an operation defined for a class of objects
- Member functions are called using a different syntax.

Member Function Syntax

- Conventional functions
  - <conventional function name> (variable name)
- Member functions
  - <variable name>.<member function name> ( )
  - for example:
    - cout<< word.length( )
    - number_of_characters = word.length( )

Declaring Variables & Constants Examples

```
const double TAX_RATE = 0.75;

int main( )
{
    int sum, counter;
    int total = 0, product = 1;
    double average;
    char repeat_program;
    string name;
```

Type Compatibility

- Mixed mode expressions
  - expressions with different data types
    - int, char, double, etc. in the same expression
- Pascal and BASIC would give a Type Mismatch Error Message and quit
- C+ + does not give any error messages for this
- Extra care is necessary for mixed mode expressions

Type Conversion

- Type promotion
  - converting a less inclusive data type into a more inclusive data type (i.e. int to double)
  - When adding an integer to a double, the compiler converts the integer to type double, adds, and gives an answer of type double.
  - int, char, and double are “compatible”

Implicit Type Conversions

int_var = double_var;	Truncates the decimals
double_var = int_var;	adds .0
int_var = char_var;	get ASCII code of char
char_var = int_var;	get the character whose ASCII code is the integer value
Ex.	
whole_num=‘A’ + 1;	66
digit = ‘5’ - ‘0’;	5

Case Changing of Character Values

```
lower_case = upper_case - ‘A’ + ‘a’;
```

OR:

```
const int CASE_CHANGE = 32;
lower_case = upper_case + CASE_CHANGE;
upper_case = lower_case - CASE_CHANGE;
```

OR:

```
lower_case = tolower (upper_case);
upper_case = toupper (lower_case);
```

Case Changing of Character Values 2

```
integer_variable = character_variable;

int_var = int (char_var);
```

Type Casts

- Type cast
  - an operation that a programmer can use to convert the data type
- Explicit type conversion
  - the use of an operation by the programmer to convert one type of data into another
- Form of type cast
  - <type name> (<expression>);
  - (<type name>) <expression>;

Explicit Type Conversion Examples

```
cout<< int (double_variable) <<endl;
cout<< (long int) integer_var;
answer = double (numerator) / double (denominator);
```

Type casting can add clarity to your program while reminding you of the data types involved in your calculations.

Explicit Type Conversion Examples 2

```
//cast a double to an int: loses decimals
int_var = (int) double_var;
//cast an int to a double: adds .0
double_var = (double) int_var;
//cast a char to an int: get ASCII code of char
int_var = (int) char_var;
//cast an int to a char: get the character if in range
char_var = (char) int_var;
```

Random Numbers

- Please refer to this program, carefully reading the comments.

Random.cpp