CSE 142
Computer Programming I

Arithmetic Expressions

Overview

Arithmetic expressions
Integer and floating-point (double) types
Unary and binary operators
Precedence
Associativity
Conversions and casts
Symbolic constants

Reading: Text sec. 2.5.

Why Study Expressions?

We need precise rules that define exactly what an expression means:

What is the value of 4 - 4 * 4 + 4?

Arithmetic on a computer may differ from everyday arithmetic or math:

(1.0 / 9.0) * 9.0 could be 0.99999998213

2 / 3 is zero in C, not .667 (!)

Assignment Statement: Review

double area, radius;

area = 3.14 * radius * radius

assignment statement
expression

Execution of an assignment statement:

Evaluate the expression on the right hand side

Store the value of the expression into the variable named on the left hand side

Expressions

Expressions are things that have values

A variable by itself is an expression: radius

A constant by itself is an expression: 3.14

Often expressions are combinations of variables, constants, and operators.

area = 3.14 * radius * radius;

Expression Evaluation

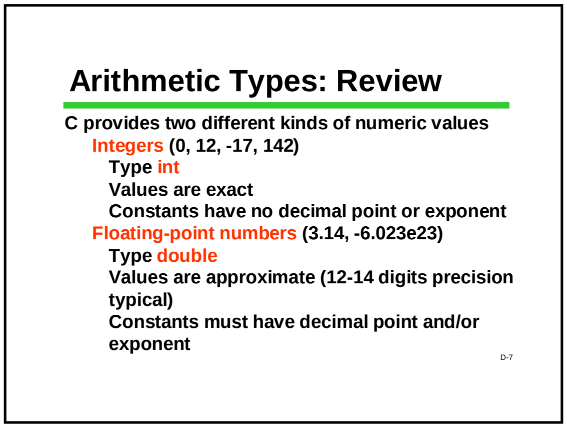
Some terminology:

Data or operand means the integer or floating-point constants and/or variables in the expression.

Operators are things like addition, multiplication, etc.

The value of an expression will depend on the data types and values and on the operators used

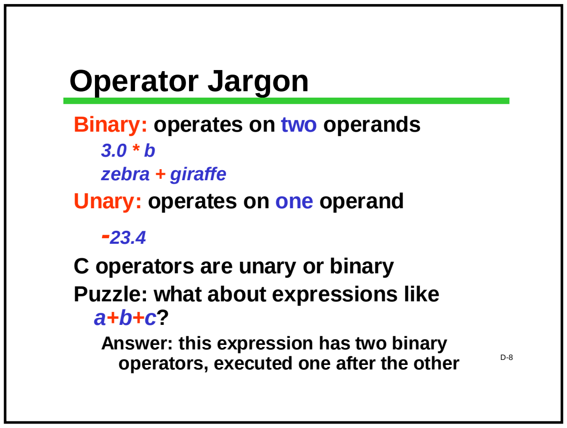
Additionally, the final result of an assignment statement will depend on the type of the assignment variable.



Arithmetic Types: Review

C provides two different kinds of numeric values

- Integers (0, 12, -17, 142)
  - Type int
  - Values are exact
  - Constants have no decimal point or exponent
- Floating-point numbers (3.14, -6.023e23)
  - Type double
  - Values are approximate (12-14 digits precision typical)
  - Constants must have decimal point and/or exponent



Operator Jargon

Binary: operates on two operands

*3.0 * b*

zebra + giraffe

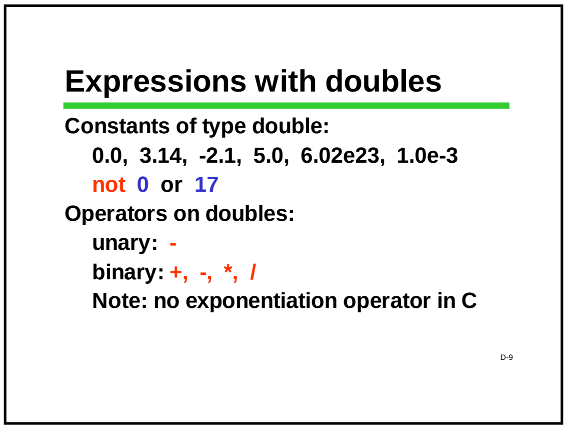
Unary: operates on one operand

-23.4

C operators are unary or binary

Puzzle: what about expressions like *a+b+c*?

Answer: this expression has two binary operators, executed one after the other



Expressions with doubles

Constants of type double:

0.0, 3.14, -2.1, 5.0, 6.02e23, 1.0e-3

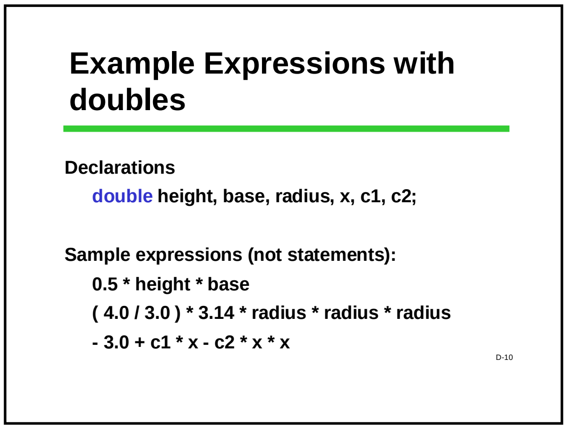
not 0 or 17

Operators on doubles:

unary: -

binary: +, -, *, /

Note: no exponentiation operator in C



Example Expressions with doubles

Declarations

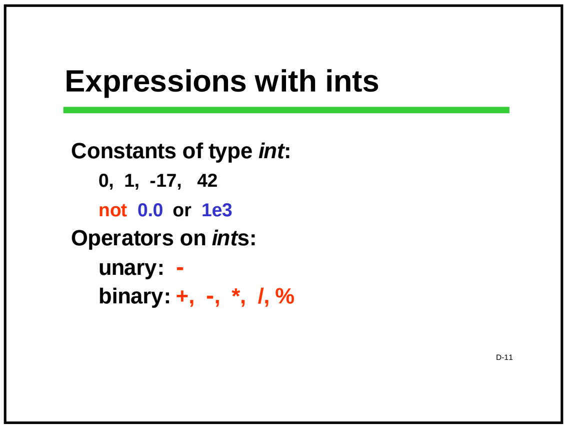
double height, base, radius, x, c1, c2;

Sample expressions (not statements):

0.5 * height * base

(4.0 / 3.0) * 3.14 * radius * radius * radius

- 3.0 + c1 * x - c2 * x * x



Expressions with ints

Constants of type *int*:

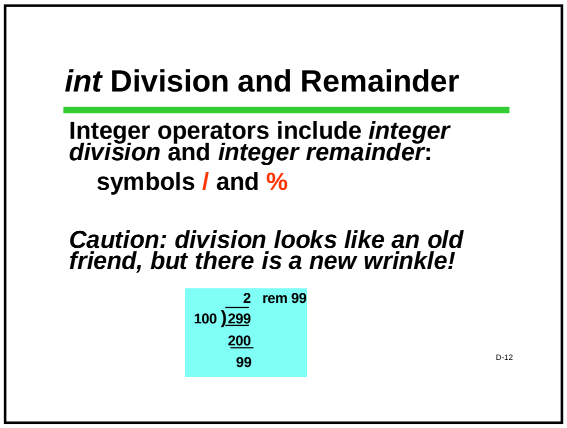
0, 1, -17,   42

not 0.0 or 1e3

Operators on *int*s:

unary: -

binary: +, -, *, /, %



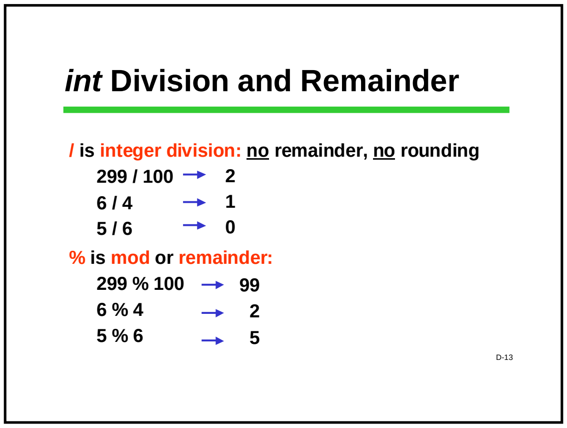
int Division and Remainder

Integer operators include *integer division* and *integer remainder*:

symbols / and %

Caution: division looks like an old friend, but there is a new wrinkle!

```
        2   rem 99
     ____
100 )299
     200
     ___
      99
```



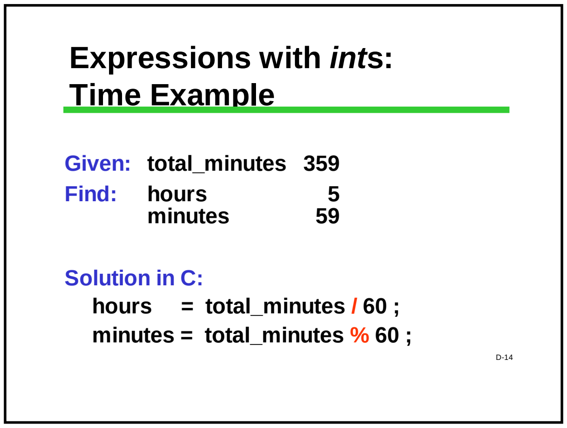
int Division and Remainder

/ is integer division: no remainder, no rounding

299 / 100 → 2
6 / 4 → 1
5 / 6 → 0

% is mod or remainder:

299 % 100 → 99
6 % 4 → 2
5 % 6 → 5

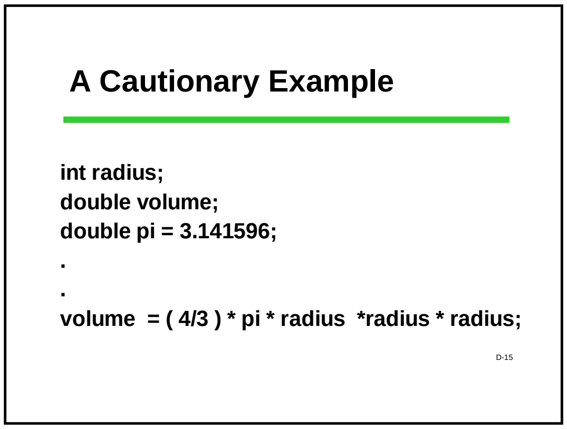


Expressions with *ints*: Time Example

Given:	total_minutes	359
Find:	hours	5
	minutes	59

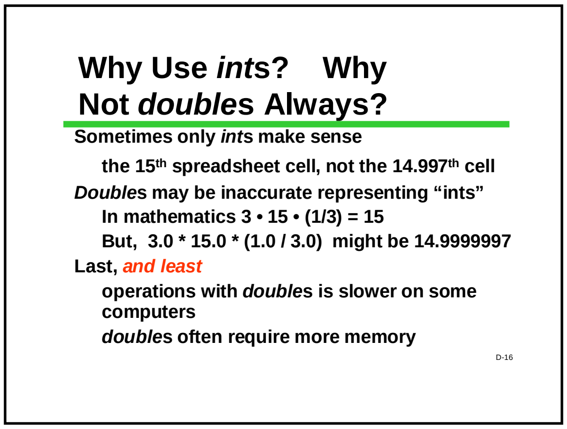
Solution in C:

```
hours   =  total_minutes / 60 ;
minutes =  total_minutes % 60 ;
```



A Cautionary Example

```
int radius;
double volume;
double pi = 3.141596;
.
.
volume  = ( 4/3 ) * pi * radius  *radius * radius;
```



Why Use *ints*? Why Not *doubles* Always?

Sometimes only *ints* make sense

the 15th spreadsheet cell, not the 14.997th cell

Doubles may be inaccurate representing "ints"

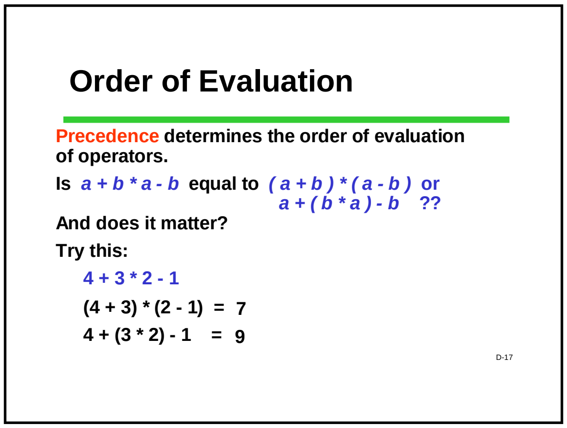
In mathematics 3 • 15 • (1/3) = 15

But, 3.0 * 15.0 * (1.0 / 3.0) might be 14.9999997

Last, *and least*

operations with *doubles* is slower on some computers

doubles often require more memory



Order of Evaluation

Precedence determines the order of evaluation of operators.

Is *a + b * a - b* equal to *(a + b) * (a - b)* or
*a + (b * a) - b* ??

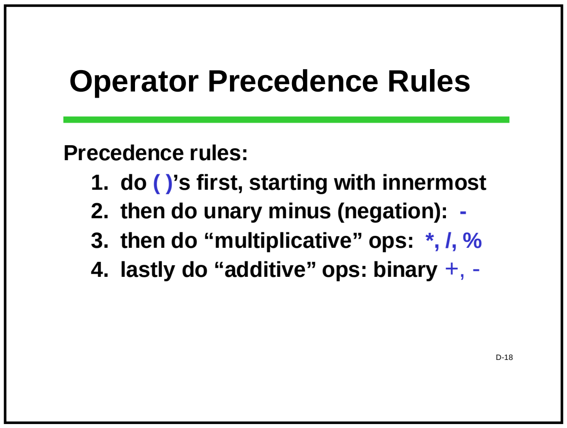
And does it matter?

Try this:

4 + 3 * 2 - 1

(4 + 3) * (2 - 1) = 7

4 + (3 * 2) - 1 = 9



Operator Precedence Rules

Precedence rules:

1. do ( )'s first, starting with innermost
2. then do unary minus (negation): -
3. then do "multiplicative" ops: *, /, %
4. lastly do "additive" ops: binary +, -

Precedence Isn’t Enough

Precedence doesn’t help if all the operators have the same precedence

*Is a / b * c* equal to

*a / (b * c)* or *(a / b) * c* ??

Associativity determines the order among consecutive operators of equal precedence

Does it matter? Try this: 15 / 4 * 2

Associativity Matters

Associativity determines the order among consecutive operators of equal precedence

Does it matter? Try this 15 / 4 * 2

(15 / 4) * 2 = 3 * 2 = 6

15 / (4 * 2) = 15 / 8 = 1

Associativity Rules

Most C arithmetic operators are “left associative”, within the same precedence level

*a / b * c* equals *(a / b) * c*

a + b - c + d equals *((a + b) - c) + d*

C also has a few operators that are right associative.

The Full Story...

C has about 50 operators & 18 precedence levels…

A "Precedence Table" shows all the operators, their precedence and associativity.

- Look on inside front cover of our textbook
- Look in any C reference manual

When in doubt: check the table

When faced with an unknown operator: check the table

Functions

C includes functions for additional calculations that are not available using operators like +, -, *, /, etc.

```
root2 = sqrt(2.0);

x = 2.1 * sin(theta/1.5) + 17.0;
```

Functions can be used in expressions just like constants or variables

We’ll find out how to create new functions a bit later in the course

Function Libraries - #include

Standard C functions are organized into *libraries*

To use a library function, you must specify the library that contains it using an #include at the top of the program

Look in the textbook (appendix C) or a C manual for lists of available libraries and functions

```
#include <math.h>
int main(void) {
  …
  root2 = sqrt(2.0);
  …
```

The <math.h> library contains sqrt, sin, cos, tan, etc.

Precedence and Associativity: Example

Mathematical formula:

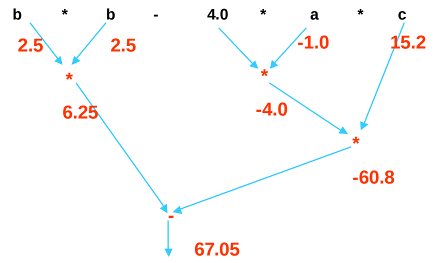
$$\frac{-b + \sqrt{b^2 - 4ac}}{2a}$$

C formula:

*(- b + sqrt (b * b - 4.0 * a * c)) / (2.0 * a)*

Depicting Expressions

b = 2.5;
a = -1.0;
c = 15.2;



Mixed Type Expressions

What is *2 * 3.14* ?

Compiler will implicitly (automatically) convert *int* to *double* when they occur together:

int + *double* → *double* + *double* (likewise -, *, /)

2*3 * 3.14 → (2*3) * 3.14 → 6 * 3.14 → 6.0 * 3.14 → 18.84

2/3 * 3.14 → (2/3) * 3.14 → 0 * 3.14 → 0.0 * 3.14 → 0.0

We strongly recommend you avoid mixed types:
e.g., use 2.0 / 3.0 * 3.14 instead.

Conversions in Assignments

```
int total, count, value;
double avg;
total = 97 ;    count = 10;
avg = total / count;    /*avg is 9.0!*/
value = total*2.2;    /*bad news*/
```

implicit conversion to double

implicit conversion to int – drops fraction with no warning

Explicit Conversions

Use a cast to explicitly convert the result of an expression to a different type

Format: *(type) expression*

Examples *(double) myage*
(int) (balance + deposit)

This does not change the rules for evaluating the expression itself (types, etc.)

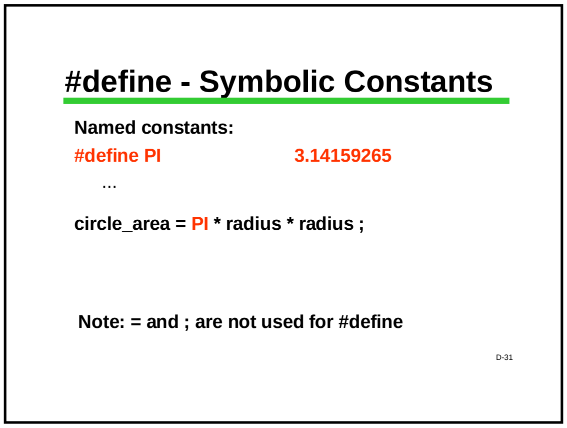
Good style, because it shows the reader that the conversion was intentional, not an accident

Using Casts

```
int total, count ;
double avg;
total = 97 ;    count = 10 ;

/* explicit conversion to double (right way)*/
avg = (double) total / (double) count;    /*avg is 9.7 */

/* explicit conversion to double (wrong way)*/
avg = (double) (total / count) ;    /*avg is 9.0*/
```



#define - Symbolic Constants

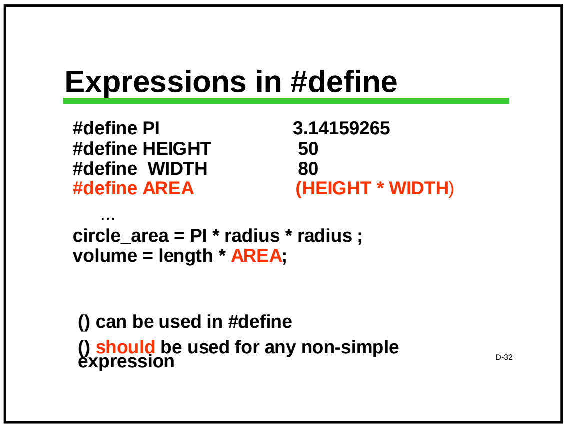
Named constants:

```
#define PI                   3.14159265
    ...

circle_area = PI * radius * radius ;
```

Note: = and ; are not used for #define

D-31



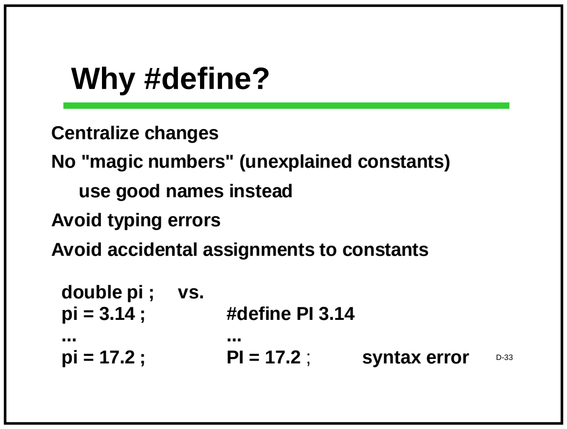
Expressions in #define

```
#define PI                  3.14159265
#define HEIGHT               50
#define  WIDTH               80
#define AREA                (HEIGHT * WIDTH)
    ...
circle_area = PI * radius * radius ;
volume = length * AREA;
```

() can be used in #define

() should be used for any non-simple expression

D-32



Why #define?

Centralize changes

No "magic numbers" (unexplained constants)

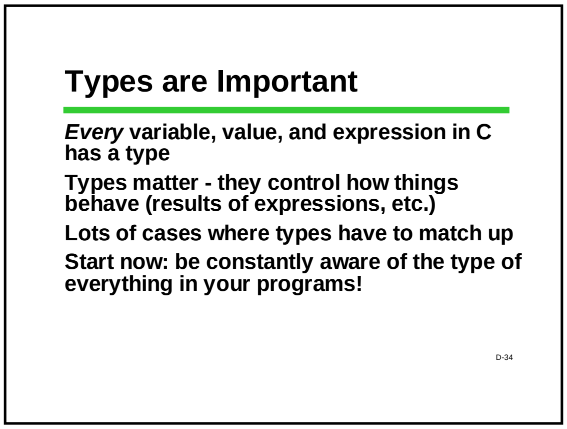
use good names instead

Avoid typing errors

Avoid accidental assignments to constants

```
double pi ;    vs.
pi = 3.14 ;             #define PI 3.14
...                     ...
pi = 17.2 ;             PI = 17.2 ;       syntax error
```

D-33



Types are Important

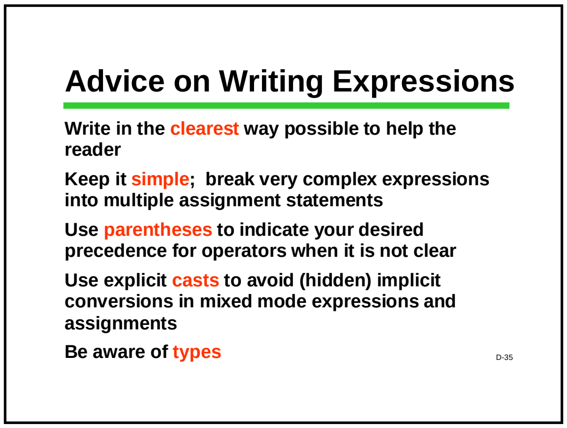
Every variable, value, and expression in C has a type

Types matter - they control how things behave (results of expressions, etc.)

Lots of cases where types have to match up

Start now: be constantly aware of the type of everything in your programs!

D-34



Advice on Writing Expressions

Write in the clearest way possible to help the reader

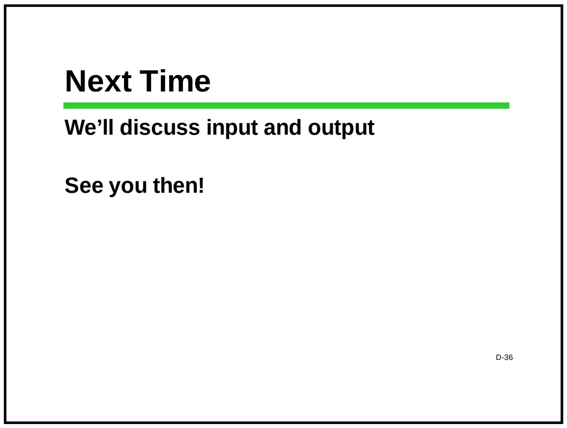
Keep it simple; break very complex expressions into multiple assignment statements

Use parentheses to indicate your desired precedence for operators when it is not clear

Use explicit casts to avoid (hidden) implicit conversions in mixed mode expressions and assignments

Be aware of types

D-35



Next Time

We'll discuss input and output

See you then!

D-36