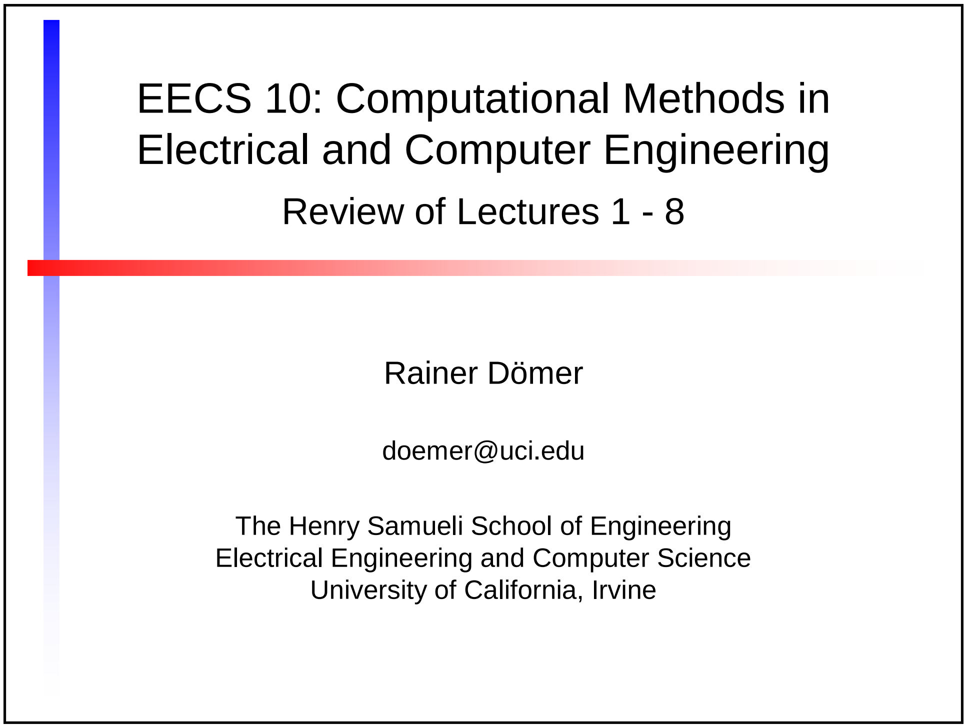

EECS 10: Computational Methods in Electrical and Computer Engineering

Review of Lectures 1 - 8

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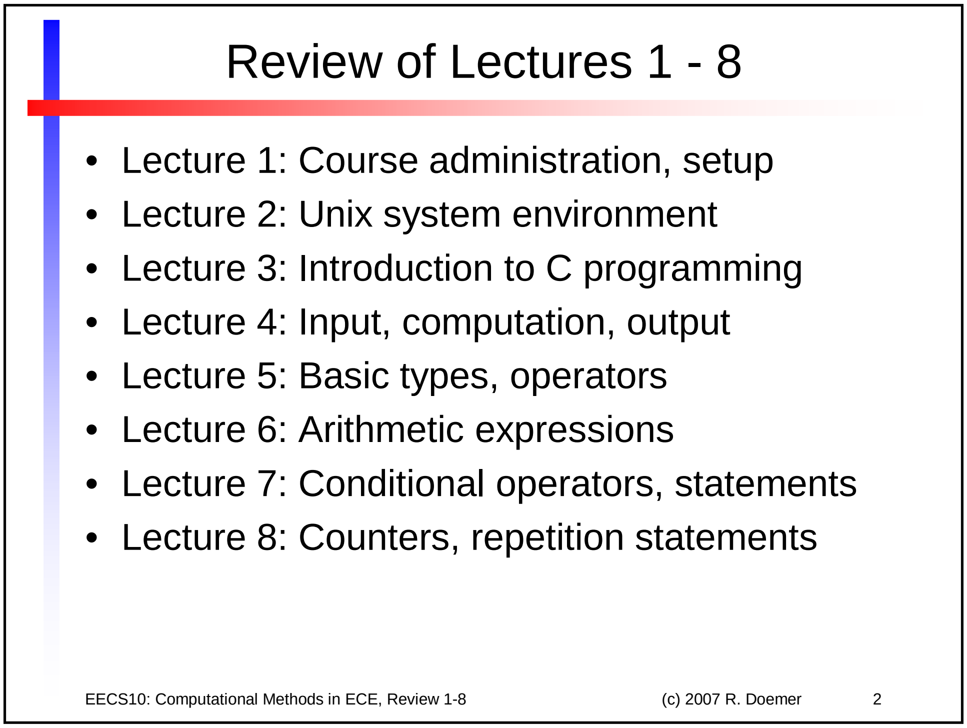
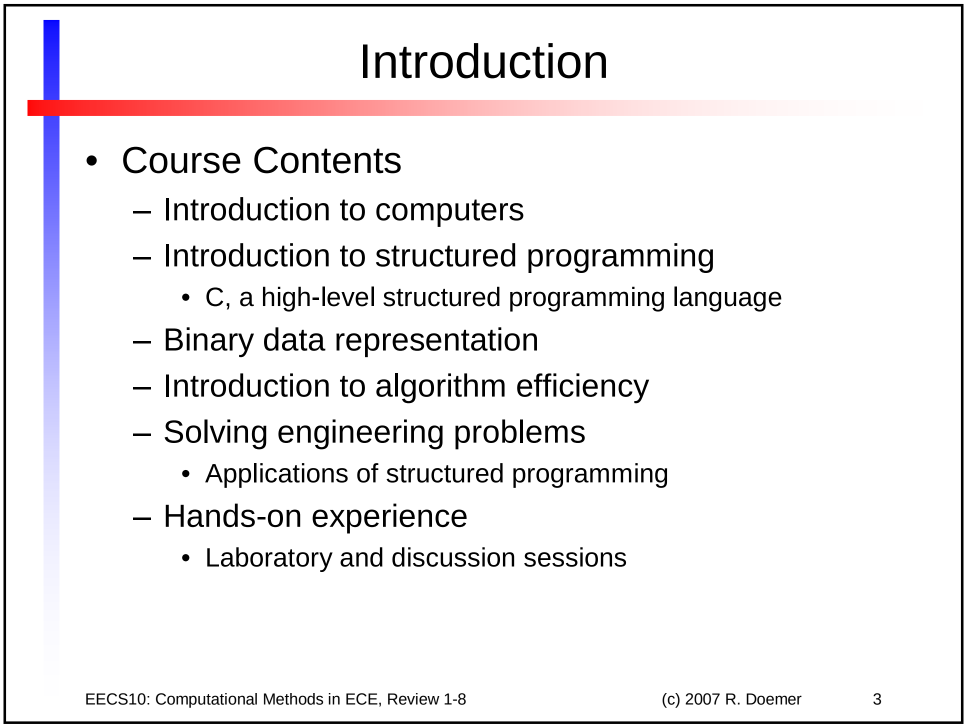


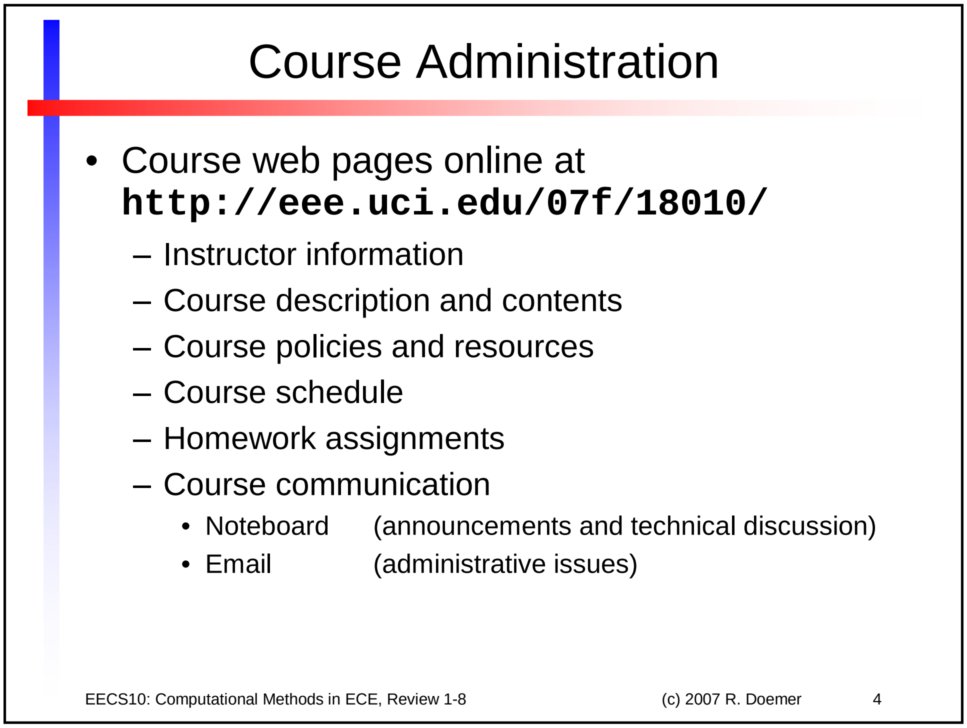
Review of Lectures 1 - 8

- Lecture 1: Course administration, setup
- Lecture 2: Unix system environment
- Lecture 3: Introduction to C programming
- Lecture 4: Input, computation, output
- Lecture 5: Basic types, operators
- Lecture 6: Arithmetic expressions
- Lecture 7: Conditional operators, statements
- Lecture 8: Counters, repetition statements



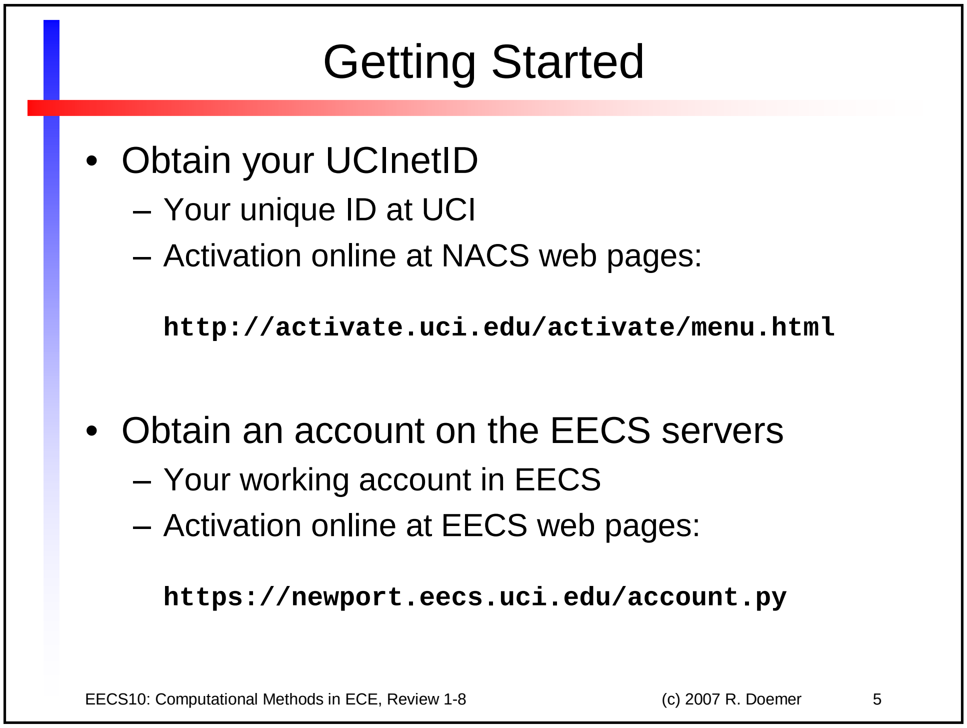
Introduction

- Course Contents
  - – Introduction to computers
  - – Introduction to structured programming
    - C, a high-level structured programming language
  - – Binary data representation
  - – Introduction to algorithm efficiency
  - – Solving engineering problems
    - Applications of structured programming
  - – Hands-on experience
    - Laboratory and discussion sessions



Course Administration

- Course web pages online at **`http://eee.uci.edu/07f/18010/`**
  - – Instructor information
  - – Course description and contents
  - – Course policies and resources
  - – Course schedule
  - – Homework assignments
  - – Course communication
    - Noteboard (announcements and technical discussion)
    - Email (administrative issues)



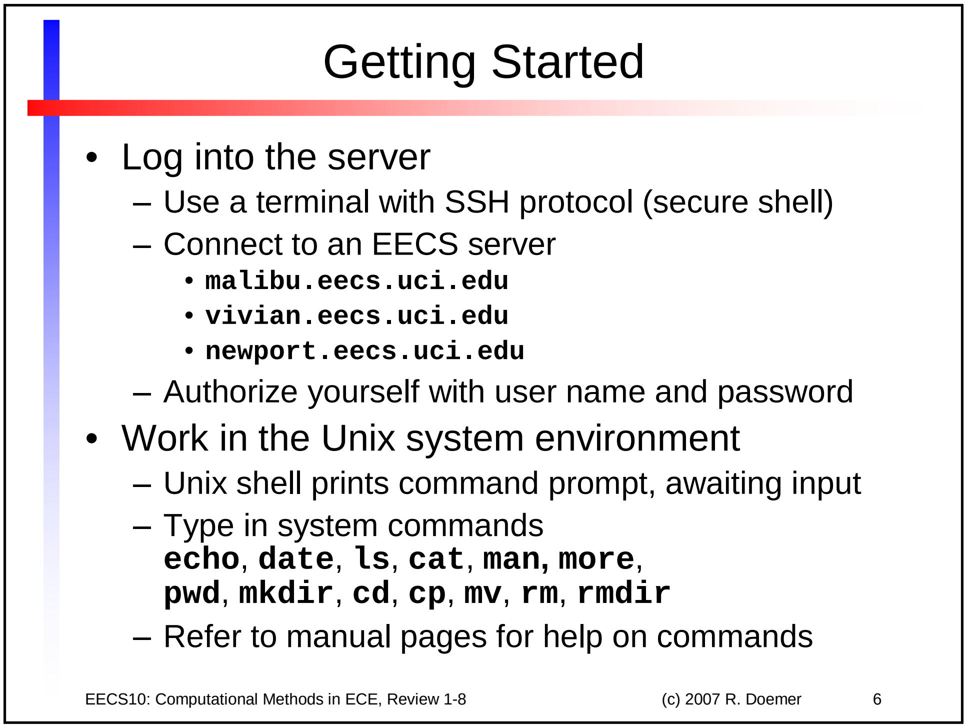
Getting Started

- Obtain your UCInetID
  - Your unique ID at UCI
  - Activation online at NACS web pages:

    `http://activate.uci.edu/activate/menu.html`

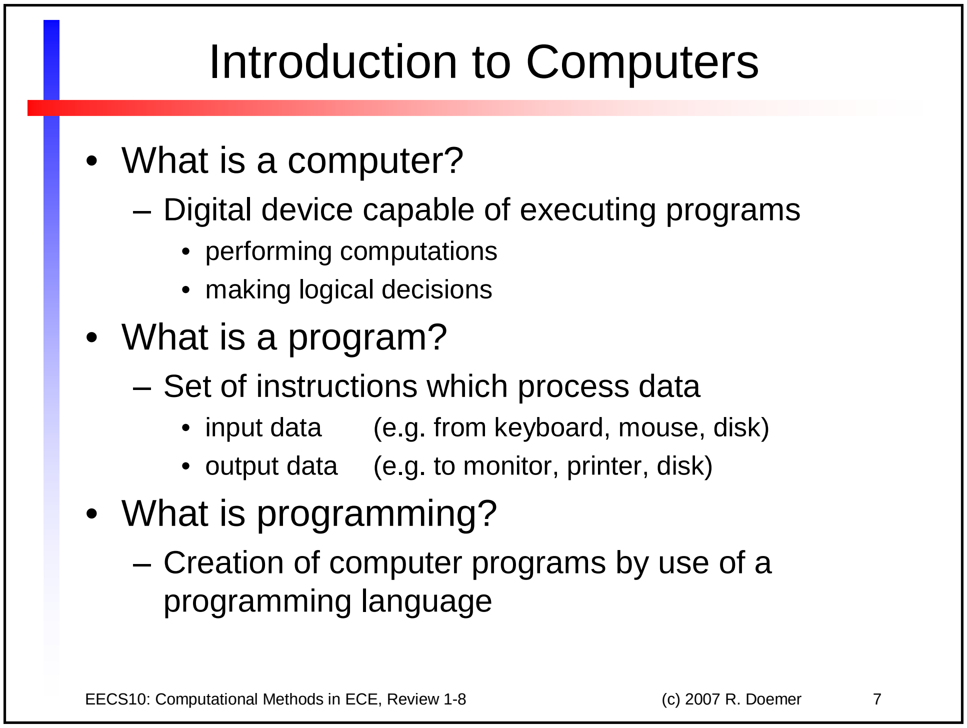
- Obtain an account on the EECS servers
  - Your working account in EECS
  - Activation online at EECS web pages:

    `https://newport.eecs.uci.edu/account.py`



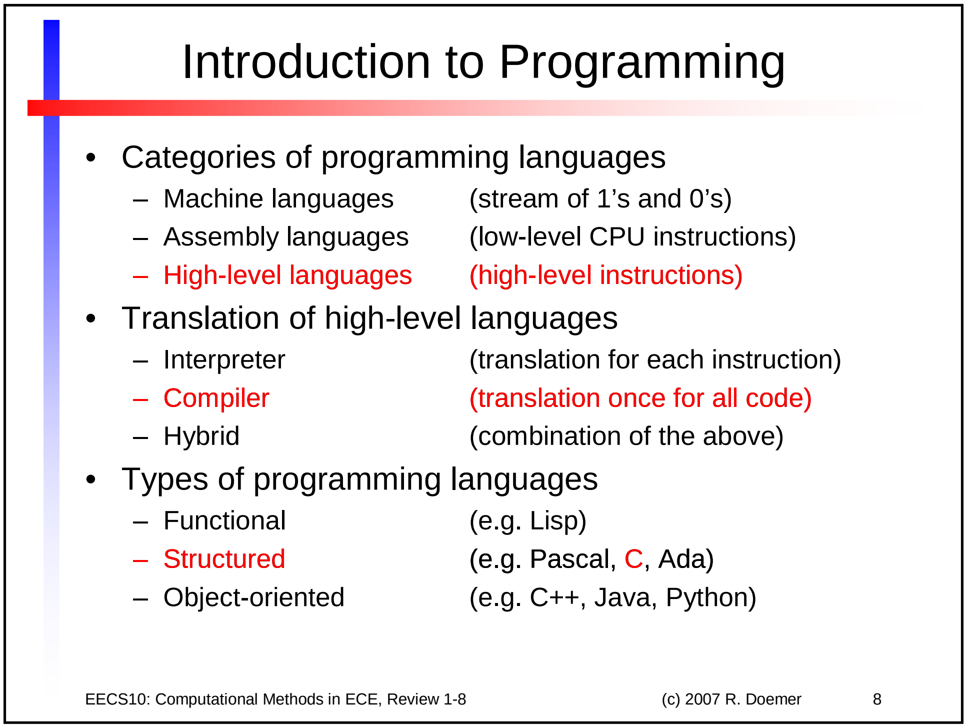
Getting Started

- Log into the server
  - Use a terminal with SSH protocol (secure shell)
  - Connect to an EECS server
    - **`malibu.eecs.uci.edu`**
    - **`vivian.eecs.uci.edu`**
    - **`newport.eecs.uci.edu`**
  - Authorize yourself with user name and password
- Work in the Unix system environment
  - Unix shell prints command prompt, awaiting input
  - Type in system commands
    `echo`, **`date`**, **`ls`**, **`cat`**, **`man`, `more`**,
    `pwd`, **`mkdir`**, **`cd`**, **`cp`**, **`mv`**, **`rm`**, **`rmdir`**
  - Refer to manual pages for help on commands



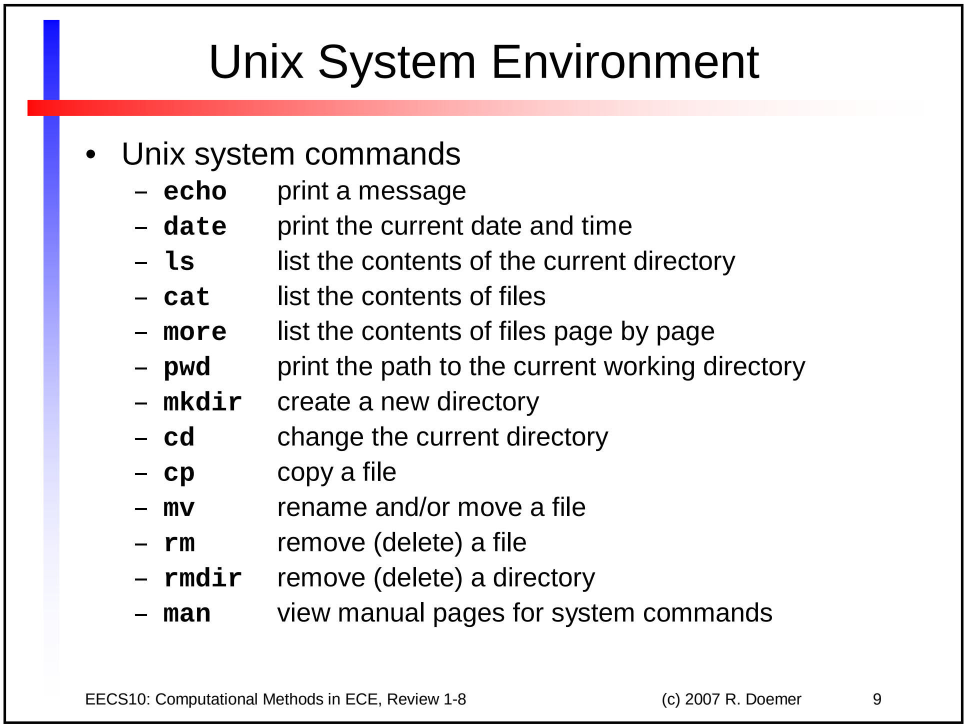
Introduction to Computers

- What is a computer?
  - – Digital device capable of executing programs
    - performing computations
    - making logical decisions
- What is a program?
  - – Set of instructions which process data
    - input data (e.g. from keyboard, mouse, disk)
    - output data (e.g. to monitor, printer, disk)
- What is programming?
  - – Creation of computer programs by use of a programming language



Introduction to Programming

- Categories of programming languages
  - – Machine languages (stream of 1's and 0's)
  - – Assembly languages (low-level CPU instructions)
  - – High-level languages (high-level instructions)
- Translation of high-level languages
  - – Interpreter (translation for each instruction)
  - – Compiler (translation once for all code)
  - – Hybrid (combination of the above)
- Types of programming languages
  - – Functional (e.g. Lisp)
  - – Structured (e.g. Pascal, C, Ada)
  - – Object-oriented (e.g. C++, Java, Python)



Unix System Environment

- Unix system commands
  - **`echo`** print a message
  - **`date`** print the current date and time
  - **`ls`** list the contents of the current directory
  - **`cat`** list the contents of files
  - **`more`** list the contents of files page by page
  - **`pwd`** print the path to the current working directory
  - **`mkdir`** create a new directory
  - **`cd`** change the current directory
  - **`cp`** copy a file
  - **`mv`** rename and/or move a file
  - **`rm`** remove (delete) a file
  - **`rmdir`** remove (delete) a directory
  - **`man`** view manual pages for system commands

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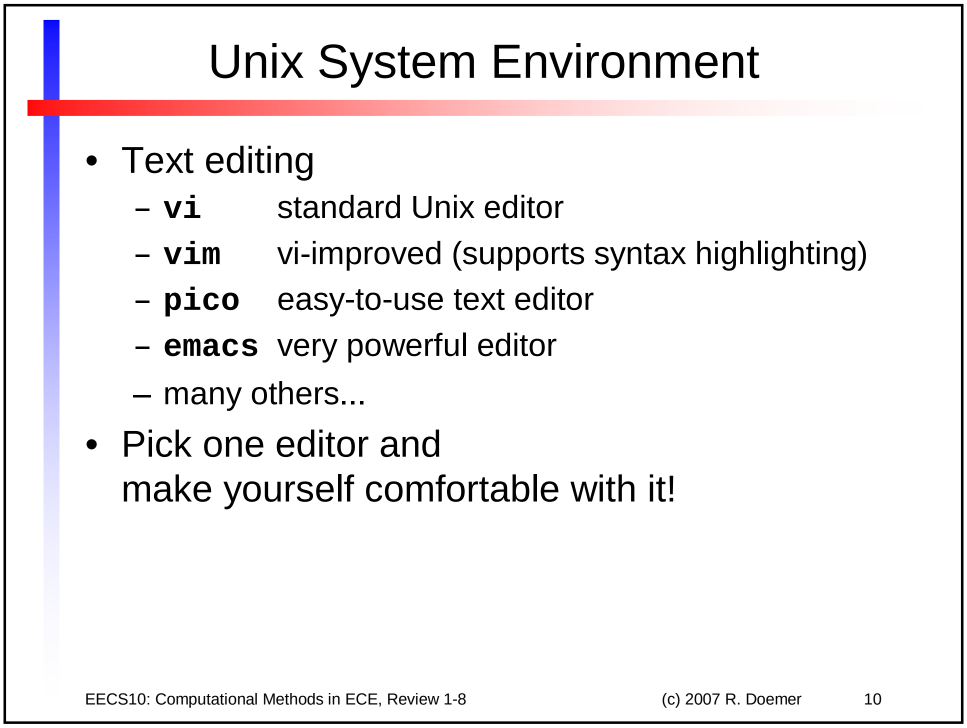

Unix System Environment

- Text editing
  - **`vi`** standard Unix editor
  - **`vim`** vi-improved (supports syntax highlighting)
  - **`pico`** easy-to-use text editor
  - **`emacs`** very powerful editor
  - many others...
- Pick one editor and
  make yourself comfortable with it!

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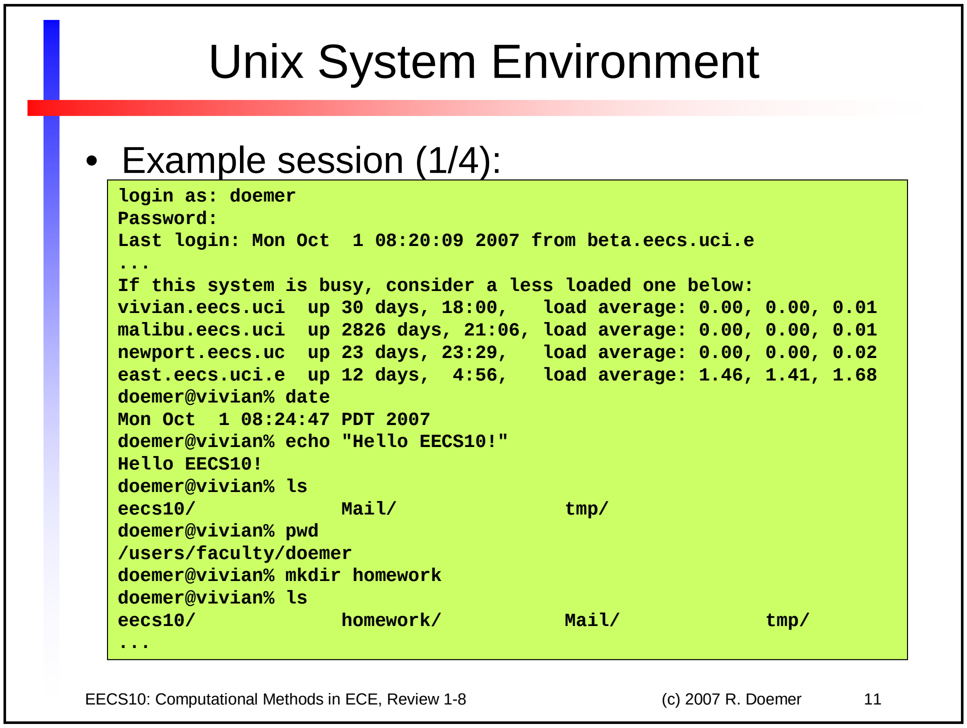
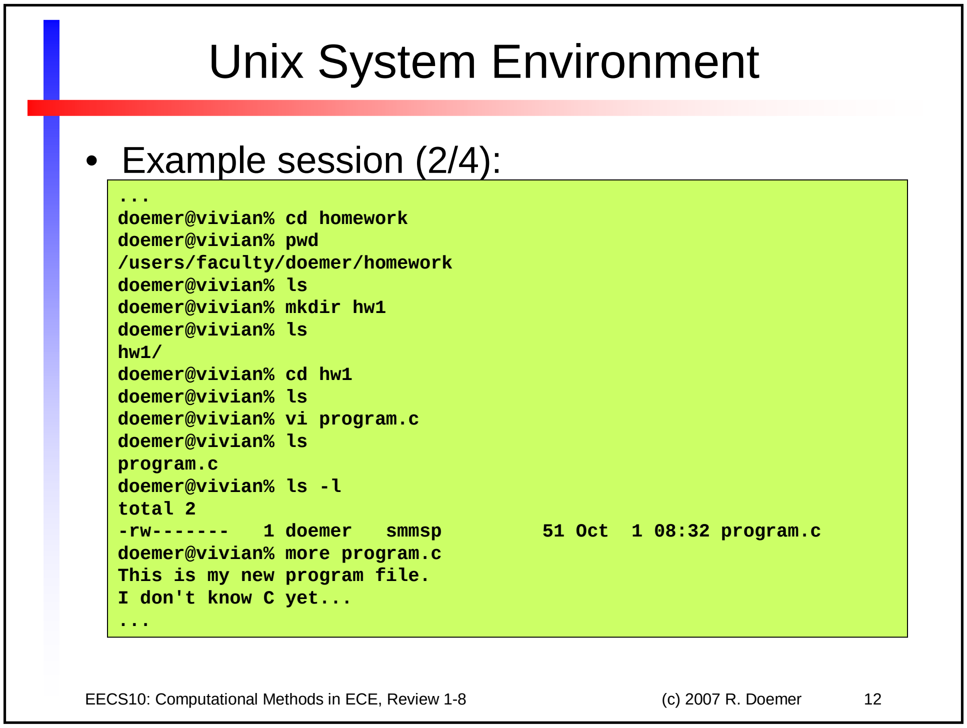


Unix System Environment

- Example session (1/4):

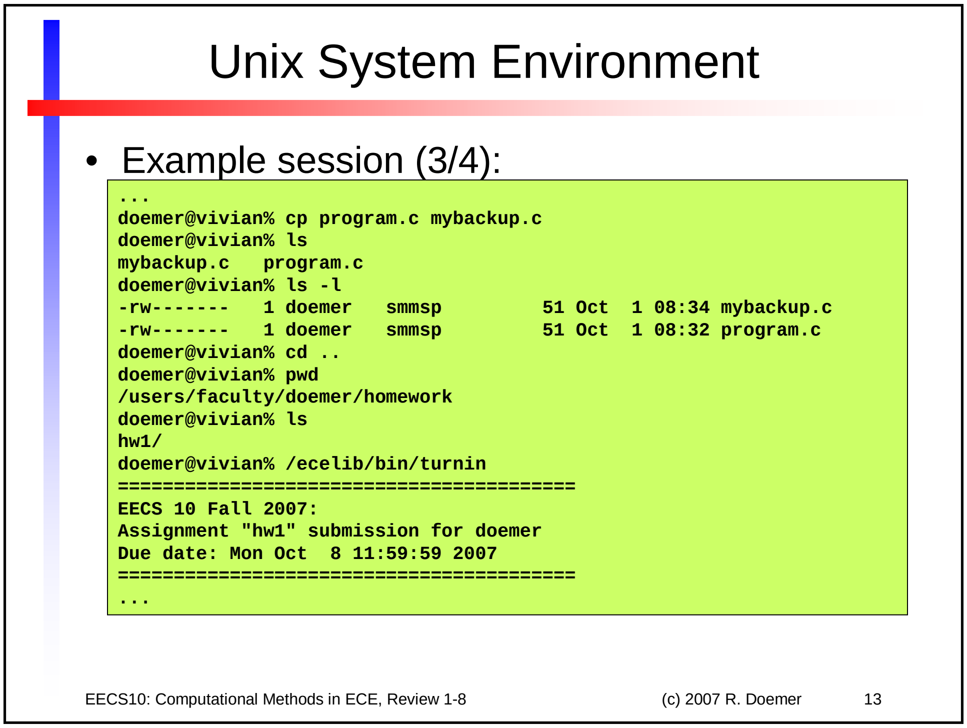
```
login as: doemer
Password:
Last login: Mon Oct  1 08:20:09 2007 from beta.eecs.uci.e
...
If this system is busy, consider a less loaded one below:
vivian.eecs.uci  up 30 days, 18:00,   load average: 0.00, 0.00, 0.01
malibu.eecs.uci  up 2826 days, 21:06, load average: 0.00, 0.00, 0.01
newport.eecs.uc  up 23 days, 23:29,   load average: 0.00, 0.00, 0.02
east.eecs.uci.e  up 12 days,  4:56,   load average: 1.46, 1.41, 1.68
doemer@vivian% date
Mon Oct  1 08:24:47 PDT 2007
doemer@vivian% echo "Hello EECS10!"
Hello EECS10!
doemer@vivian% ls
eecs10/             Mail/               tmp/
doemer@vivian% pwd
/users/faculty/doemer
doemer@vivian% mkdir homework
doemer@vivian% ls
eecs10/             homework/           Mail/             tmp/
...
```



Unix System Environment

- Example session (2/4):

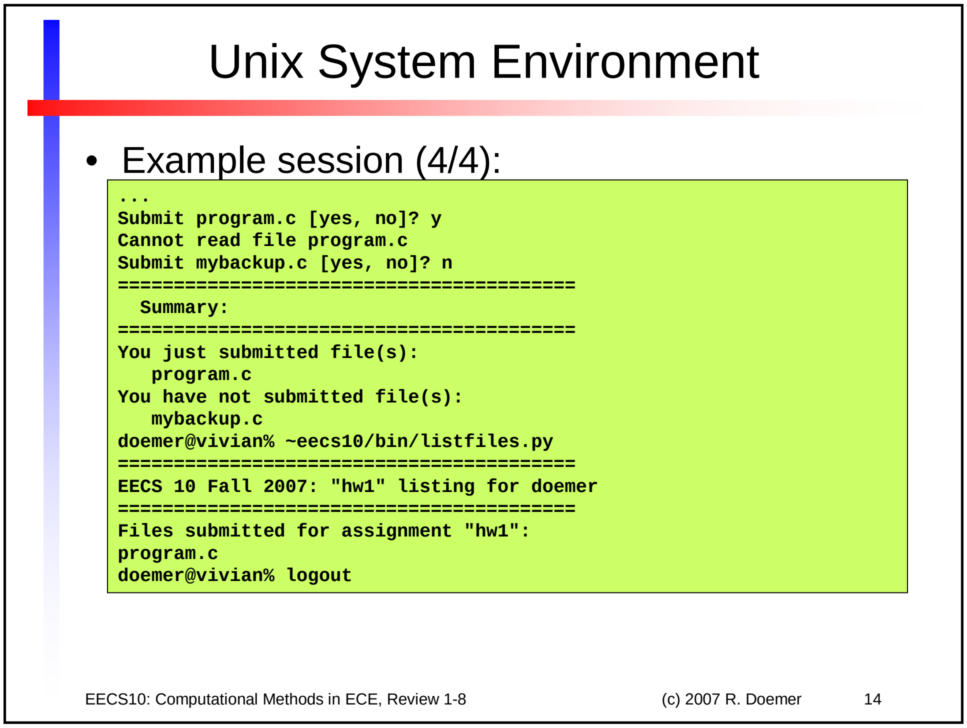
```
...
doemer@vivian% cd homework
doemer@vivian% pwd
/users/faculty/doemer/homework
doemer@vivian% ls
doemer@vivian% mkdir hw1
doemer@vivian% ls
hw1/
doemer@vivian% cd hw1
doemer@vivian% ls
doemer@vivian% vi program.c
doemer@vivian% ls
program.c
doemer@vivian% ls -l
total 2
-rw-------   1 doemer   smmsp         51 Oct  1 08:32 program.c
doemer@vivian% more program.c
This is my new program file.
I don't know C yet...
...
```



Unix System Environment

- Example session (3/4):

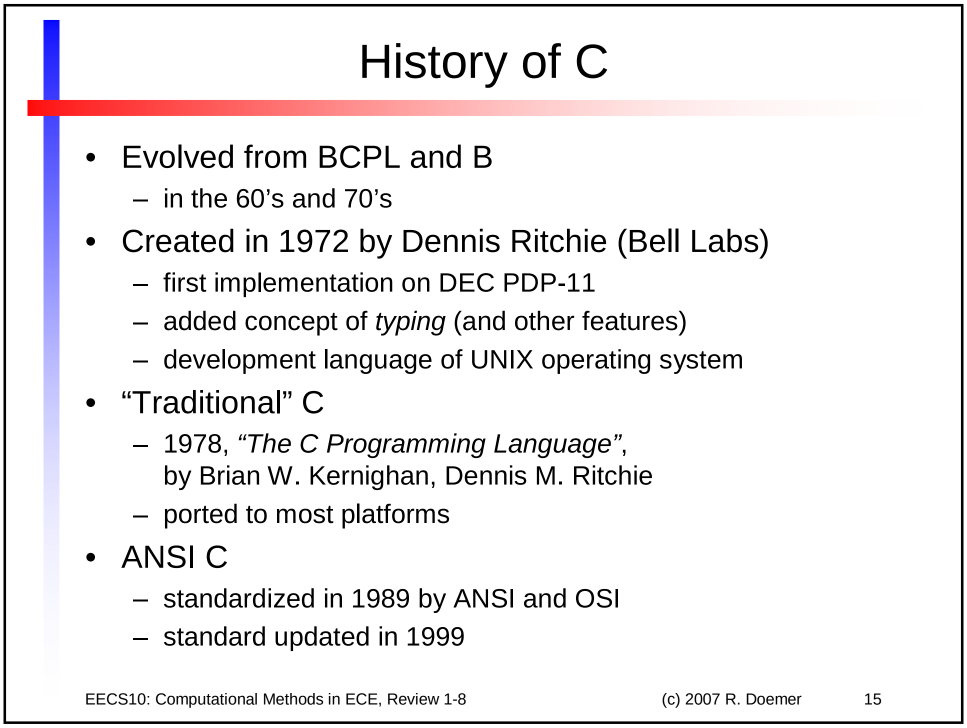
```
...
doemer@vivian% cp program.c mybackup.c
doemer@vivian% ls
mybackup.c   program.c
doemer@vivian% ls -l
-rw-------   1 doemer   smmsp         51 Oct  1 08:34 mybackup.c
-rw-------   1 doemer   smmsp         51 Oct  1 08:32 program.c
doemer@vivian% cd ..
doemer@vivian% pwd
/users/faculty/doemer/homework
doemer@vivian% ls
hw1/
doemer@vivian% /ecelib/bin/turnin
=========================================
EECS 10 Fall 2007:
Assignment "hw1" submission for doemer
Due date: Mon Oct  8 11:59:59 2007
=========================================
...
```



Unix System Environment

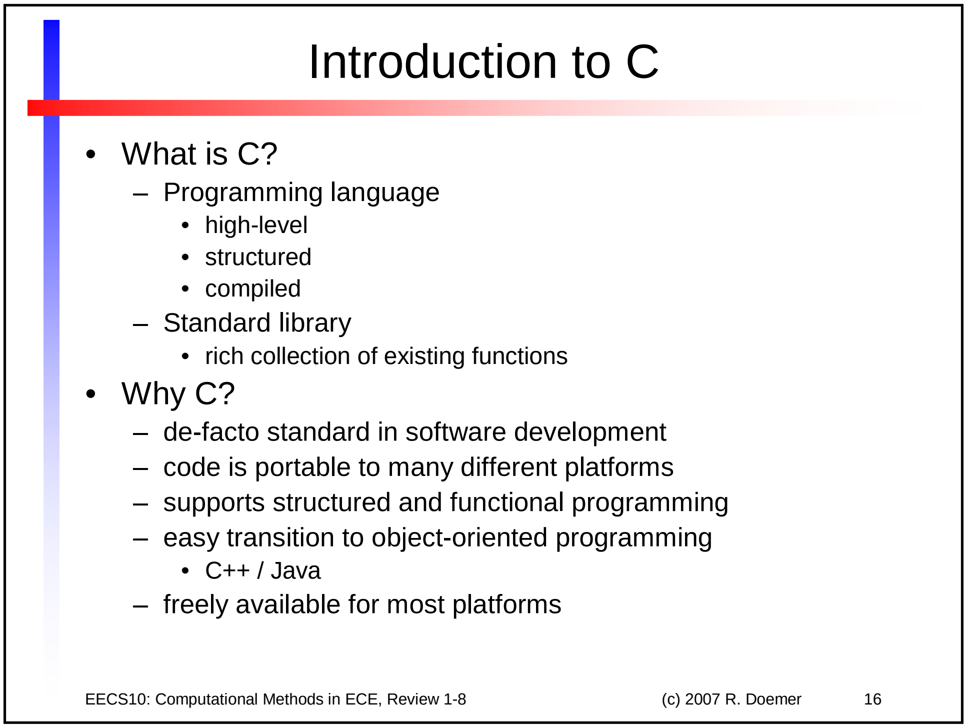
- Example session (4/4):

```
...
Submit program.c [yes, no]? y
Cannot read file program.c
Submit mybackup.c [yes, no]? n
=========================================
  Summary:
=========================================
You just submitted file(s):
   program.c
You have not submitted file(s):
   mybackup.c
doemer@vivian% ~eecs10/bin/listfiles.py
=========================================
EECS 10 Fall 2007: "hw1" listing for doemer
=========================================
Files submitted for assignment "hw1":
program.c
doemer@vivian% logout
```



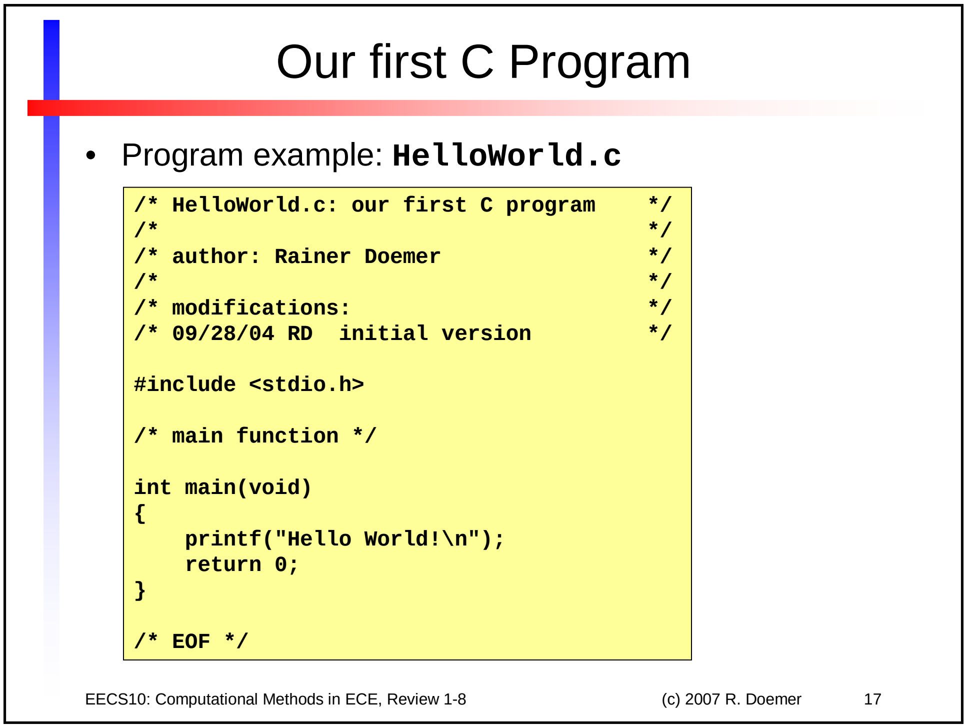
History of C

- Evolved from BCPL and B
  - in the 60's and 70's
- Created in 1972 by Dennis Ritchie (Bell Labs)
  - first implementation on DEC PDP-11
  - added concept of *typing* (and other features)
  - development language of UNIX operating system
- "Traditional" C
  - 1978, *"The C Programming Language"*,
    by Brian W. Kernighan, Dennis M. Ritchie
  - ported to most platforms
- ANSI C
  - standardized in 1989 by ANSI and OSI
  - standard updated in 1999



Introduction to C

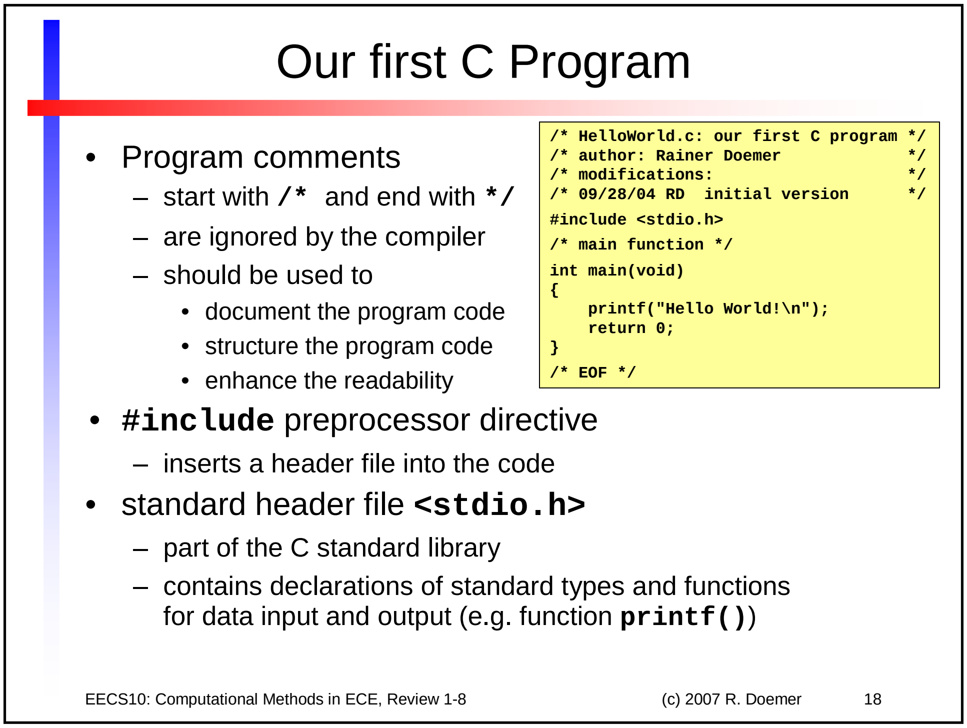
- What is C?
  - Programming language
    - high-level
    - structured
    - compiled
  - Standard library
    - rich collection of existing functions
- Why C?
  - de-facto standard in software development
  - code is portable to many different platforms
  - supports structured and functional programming
  - easy transition to object-oriented programming
    - C++ / Java
  - freely available for most platforms



Our first C Program

- Program example: **`HelloWorld.c`**

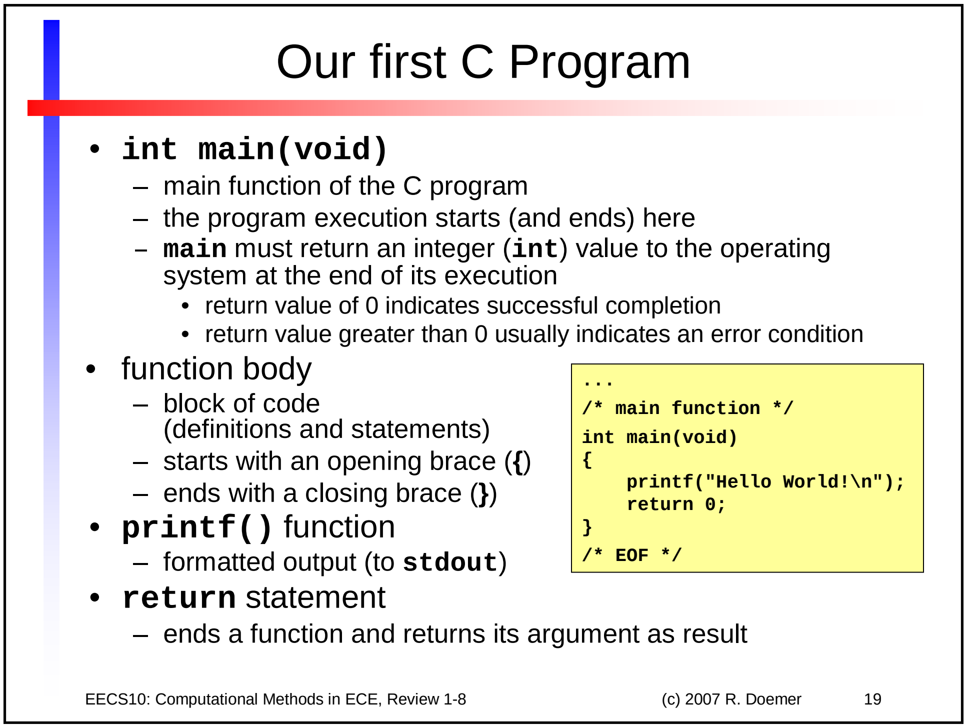
```
/* HelloWorld.c: our first C program    */
/*                                       */
/* author: Rainer Doemer                 */
/*                                       */
/* modifications:                        */
/* 09/28/04 RD  initial version          */

#include <stdio.h>

/* main function */

int main(void)
{
    printf("Hello World!\n");
    return 0;
}

/* EOF */
```



Our first C Program

- Program comments
  - start with **`/*`** and end with **`*/`**
  - are ignored by the compiler
  - should be used to
    - document the program code
    - structure the program code
    - enhance the readability
- **`#include`** preprocessor directive
  - inserts a header file into the code
- standard header file **`<stdio.h>`**
  - part of the C standard library
  - contains declarations of standard types and functions for data input and output (e.g. function **`printf()`**)

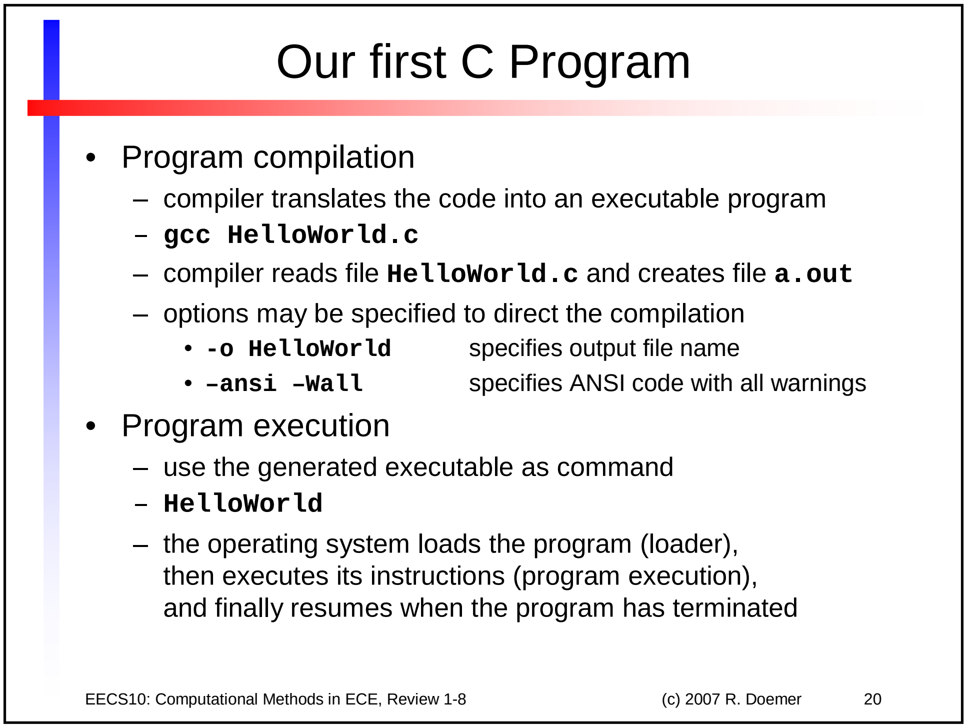
```
/* HelloWorld.c: our first C program */
/* author: Rainer Doemer             */
/* modifications:                    */
/* 09/28/04 RD  initial version      */
#include <stdio.h>
/* main function */
int main(void)
{
    printf("Hello World!\n");
    return 0;
}
/* EOF */
```



Our first C Program

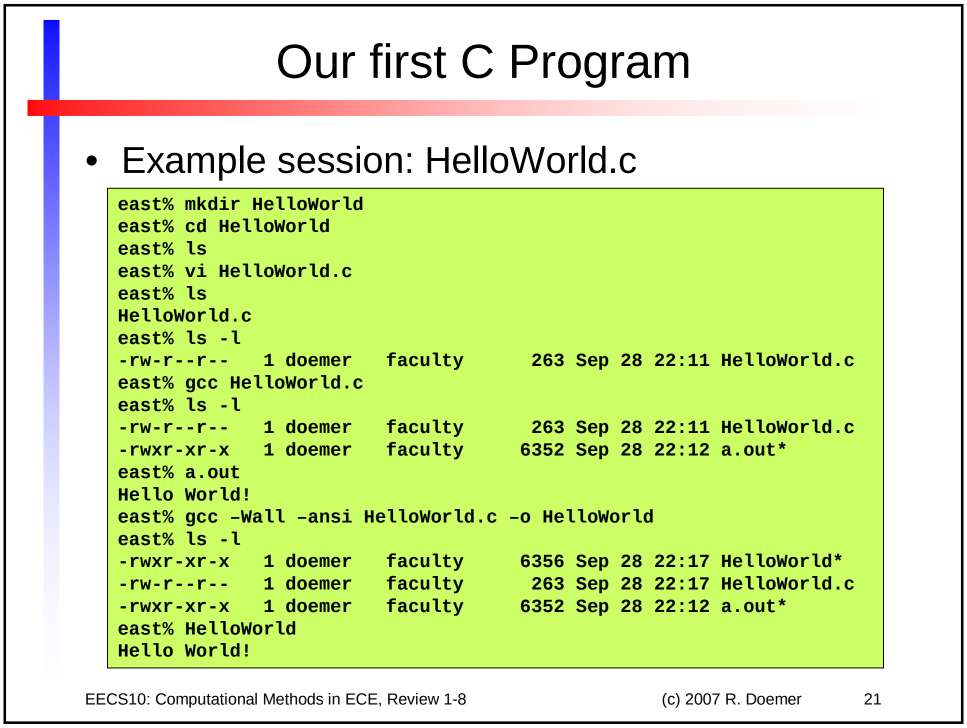
- **`int main(void)`**
  - main function of the C program
  - the program execution starts (and ends) here
  - **`main`** must return an integer (**`int`**) value to the operating system at the end of its execution
    - return value of 0 indicates successful completion
    - return value greater than 0 usually indicates an error condition
- function body
  - block of code (definitions and statements)
  - starts with an opening brace (**{**)
  - ends with a closing brace (**}**)
- **`printf()`** function
  - formatted output (to **`stdout`**)
- **`return`** statement
  - ends a function and returns its argument as result

```
...
/* main function */
int main(void)
{
    printf("Hello World!\n");
    return 0;
}
/* EOF */
```



Our first C Program

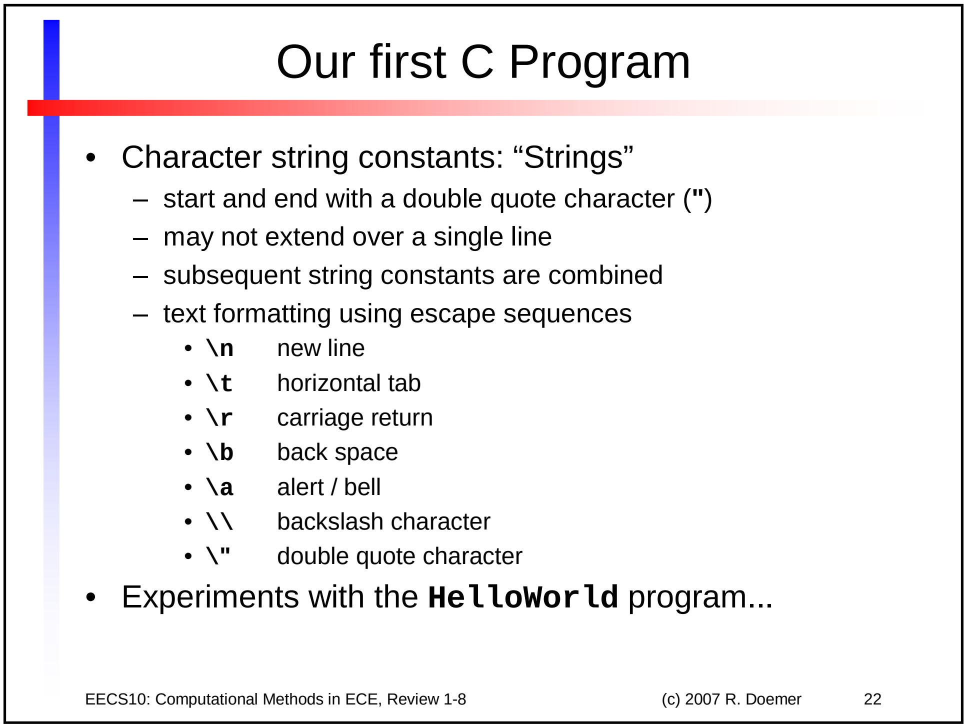
- Program compilation
  - compiler translates the code into an executable program
  - **`gcc HelloWorld.c`**
  - compiler reads file **`HelloWorld.c`** and creates file **`a.out`**
  - options may be specified to direct the compilation
    - **`-o HelloWorld`** specifies output file name
    - **`–ansi –Wall`** specifies ANSI code with all warnings
- Program execution
  - use the generated executable as command
  - **`HelloWorld`**
  - the operating system loads the program (loader), then executes its instructions (program execution), and finally resumes when the program has terminated



Our first C Program

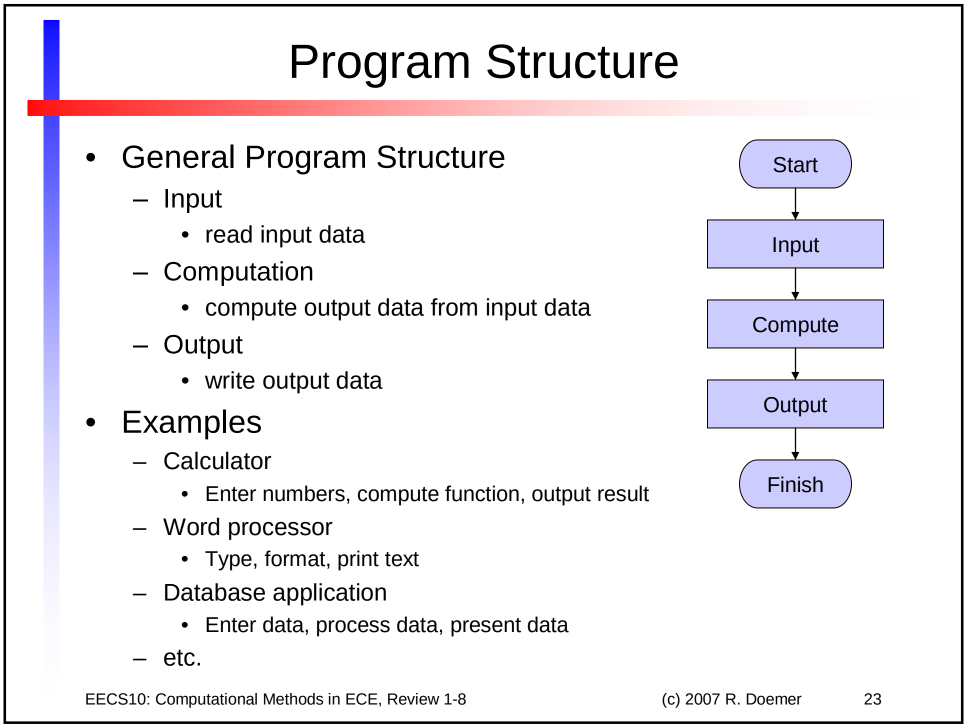
- Example session: HelloWorld.c

```
east% mkdir HelloWorld
east% cd HelloWorld
east% ls
east% vi HelloWorld.c
east% ls
HelloWorld.c
east% ls -l
-rw-r--r--   1 doemer   faculty      263 Sep 28 22:11 HelloWorld.c
east% gcc HelloWorld.c
east% ls -l
-rw-r--r--   1 doemer   faculty      263 Sep 28 22:11 HelloWorld.c
-rwxr-xr-x   1 doemer   faculty     6352 Sep 28 22:12 a.out*
east% a.out
Hello World!
east% gcc -Wall -ansi HelloWorld.c -o HelloWorld
east% ls -l
-rwxr-xr-x   1 doemer   faculty     6356 Sep 28 22:17 HelloWorld*
-rw-r--r--   1 doemer   faculty      263 Sep 28 22:17 HelloWorld.c
-rwxr-xr-x   1 doemer   faculty     6352 Sep 28 22:12 a.out*
east% HelloWorld
Hello World!
```



Our first C Program

- Character string constants: “Strings”
  - start and end with a double quote character (**"**)
  - may not extend over a single line
  - subsequent string constants are combined
  - text formatting using escape sequences
    - **\n** new line
    - **\t** horizontal tab
    - **\r** carriage return
    - **\b** back space
    - **\a** alert / bell
    - \\ backslash character
    - **\"** double quote character
- Experiments with the **HelloWorld** program...



Program Structure

- General Program Structure
  - Input
    - read input data
  - Computation
    - compute output data from input data
  - Output
    - write output data
- Examples
  - Calculator
    - Enter numbers, compute function, output result
  - Word processor
    - Type, format, print text
  - Database application
    - Enter data, process data, present data
  - etc.

Start

Input

Compute

Output

Finish

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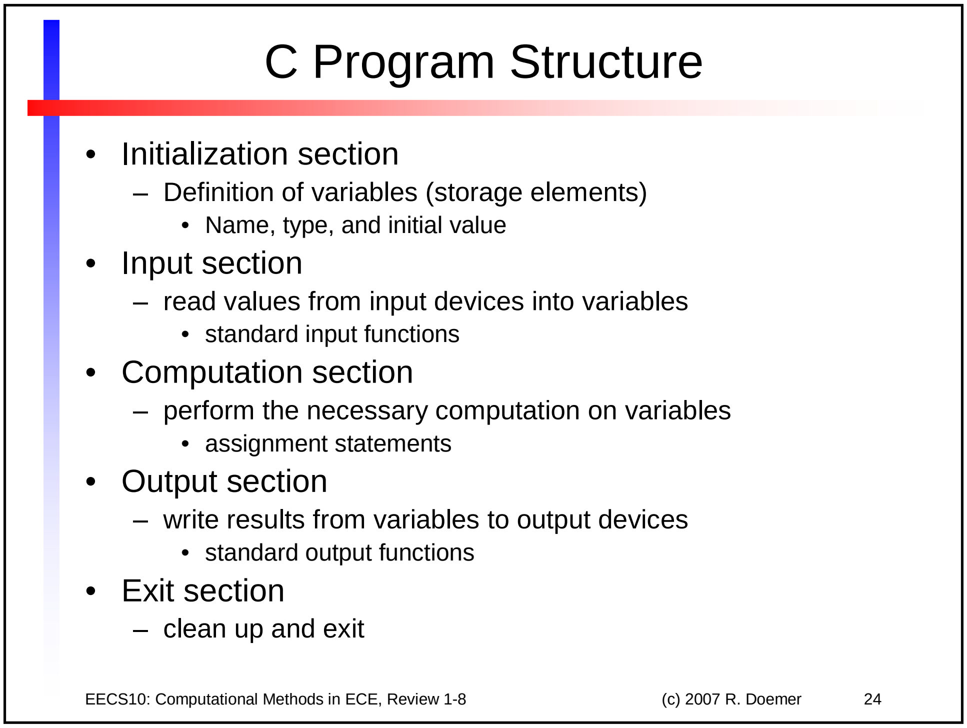

C Program Structure

- Initialization section
  - Definition of variables (storage elements)
    - Name, type, and initial value
- Input section
  - read values from input devices into variables
    - standard input functions
- Computation section
  - perform the necessary computation on variables
    - assignment statements
- Output section
  - write results from variables to output devices
    - standard output functions
- Exit section
  - clean up and exit

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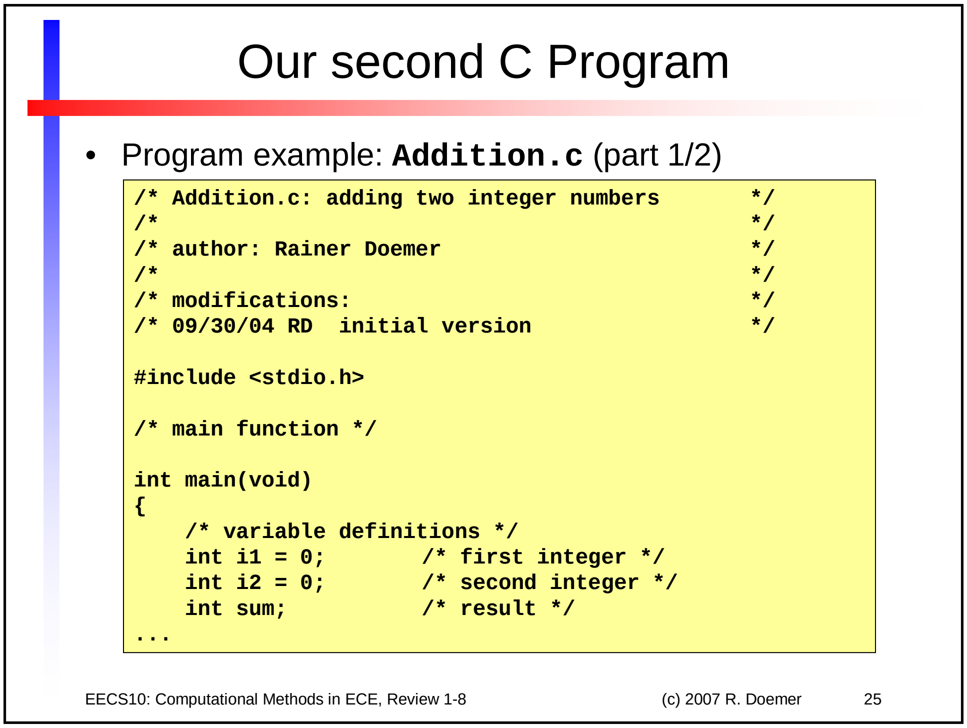

Our second C Program

- Program example: **`Addition.c`** (part 1/2)

```
/* Addition.c: adding two integer numbers       */
/*                                              */
/* author: Rainer Doemer                        */
/*                                              */
/* modifications:                               */
/* 09/30/04 RD  initial version                 */

#include <stdio.h>

/* main function */

int main(void)
{
    /* variable definitions */
    int i1 = 0;       /* first integer */
    int i2 = 0;       /* second integer */
    int sum;          /* result */
...
```

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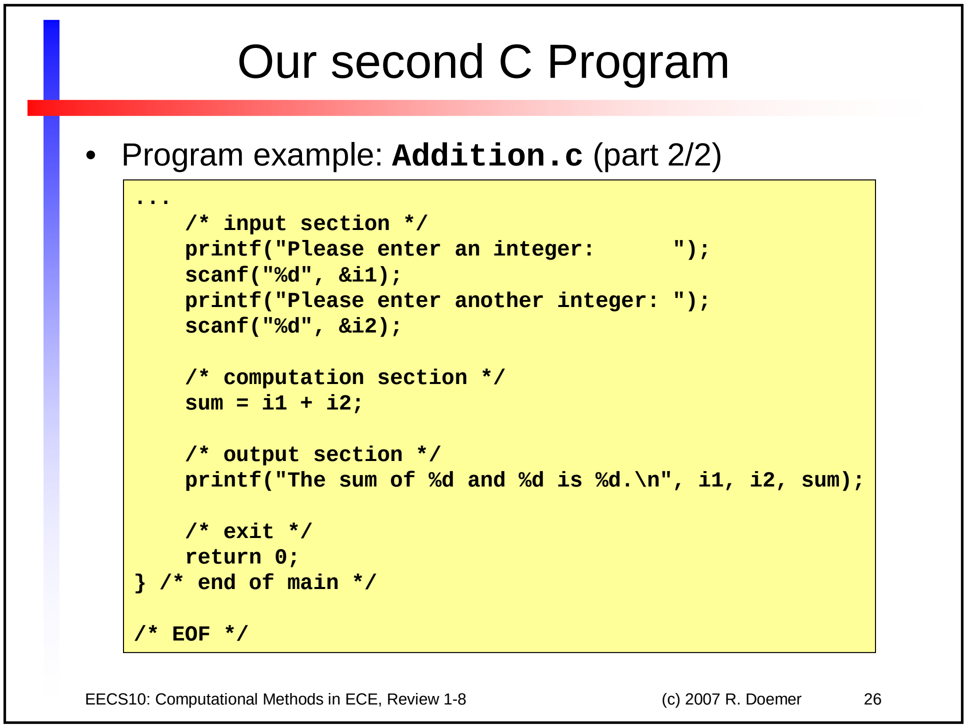

Our second C Program

- Program example: **`Addition.c`** (part 2/2)

```
...
    /* input section */
    printf("Please enter an integer:      ");
    scanf("%d", &i1);
    printf("Please enter another integer: ");
    scanf("%d", &i2);

    /* computation section */
    sum = i1 + i2;

    /* output section */
    printf("The sum of %d and %d is %d.\n", i1, i2, sum);

    /* exit */
    return 0;
} /* end of main */

/* EOF */
```

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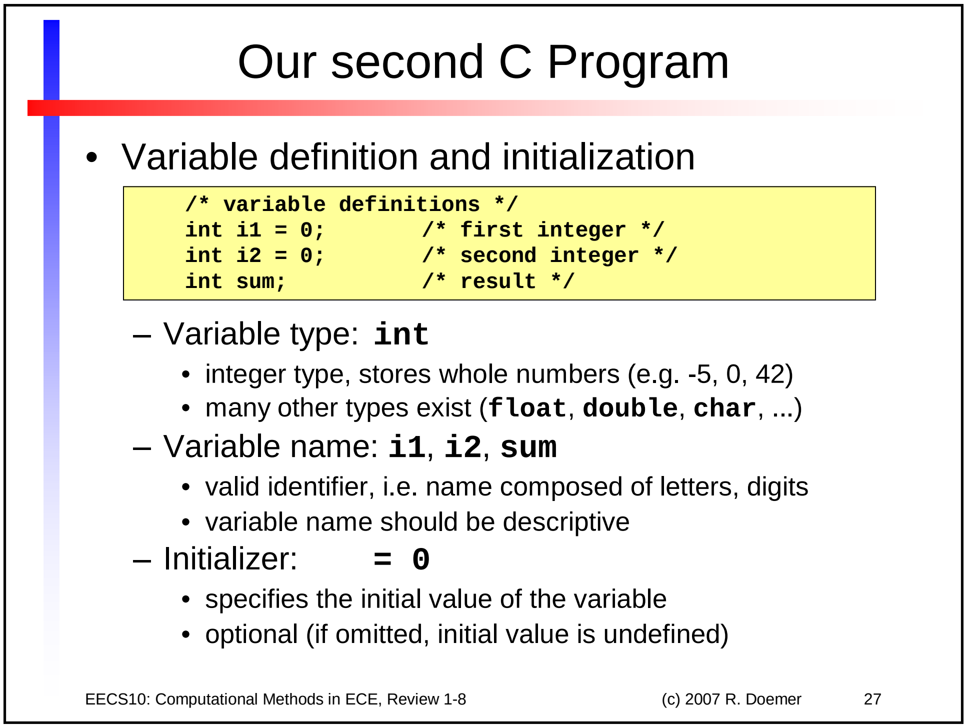
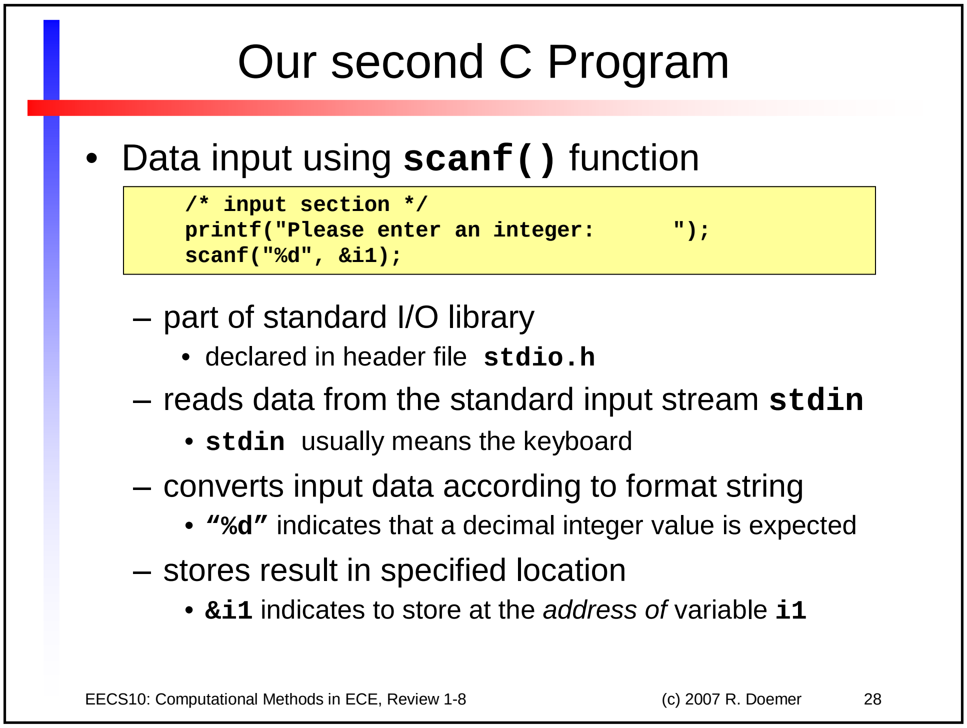


Our second C Program

- Variable definition and initialization

```
/* variable definitions */
int i1 = 0;        /* first integer */
int i2 = 0;        /* second integer */
int sum;           /* result */
```

- – Variable type: **`int`**
  - integer type, stores whole numbers (e.g. -5, 0, 42)
  - many other types exist (**`float`**, **`double`**, **`char`**, ...)
- – Variable name: **`i1`**, **`i2`**, **`sum`**
  - valid identifier, i.e. name composed of letters, digits
  - variable name should be descriptive
- – Initializer: **`= 0`**
  - specifies the initial value of the variable
  - optional (if omitted, initial value is undefined)

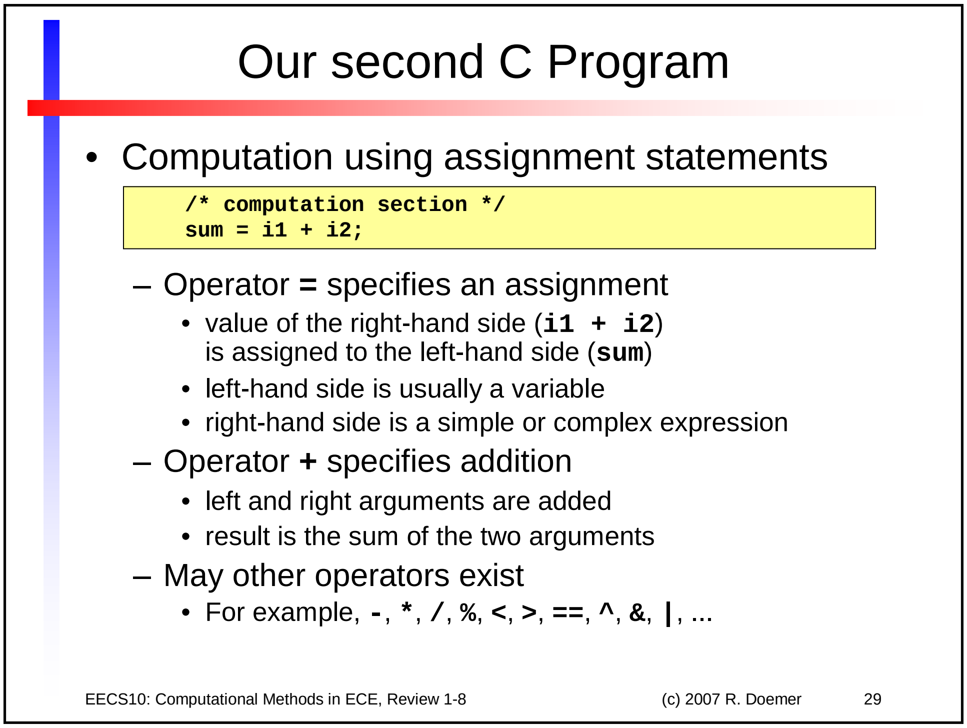


Our second C Program

- Data input using **`scanf()`** function

```
/* input section */
printf("Please enter an integer:      ");
scanf("%d", &i1);
```

- – part of standard I/O library
  - declared in header file **`stdio.h`**
- – reads data from the standard input stream **`stdin`**
  - **`stdin`** usually means the keyboard
- – converts input data according to format string
  - **`“%d”`** indicates that a decimal integer value is expected
- – stores result in specified location
  - **`&i1`** indicates to store at the *address of* variable **`i1`**

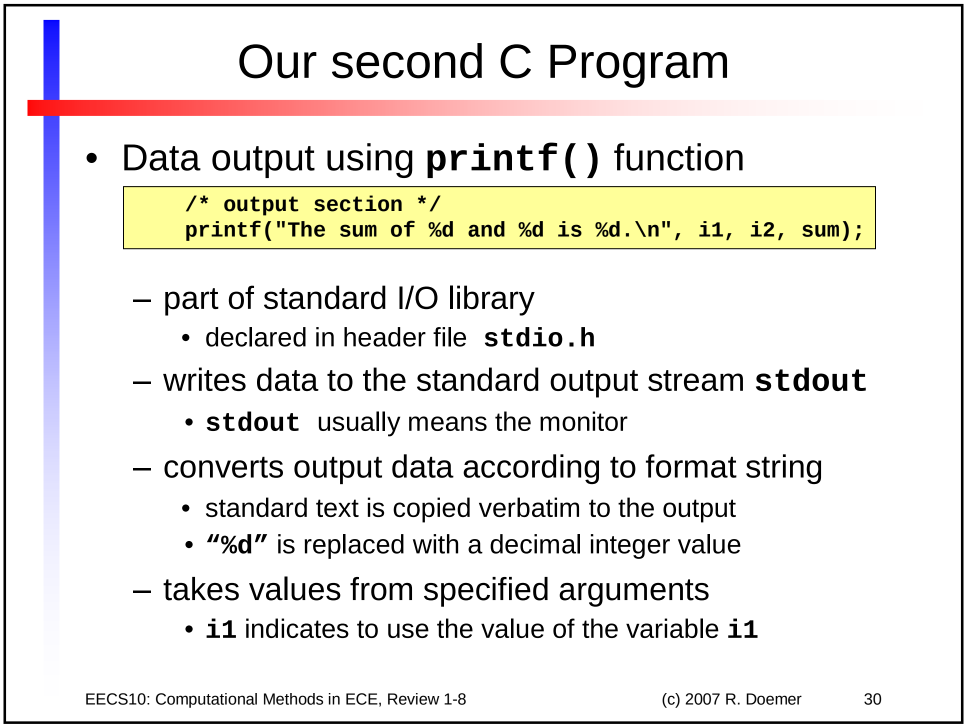


Our second C Program

- Computation using assignment statements

```
/* computation section */
sum = i1 + i2;
```

  - Operator **=** specifies an assignment
    - value of the right-hand side (**i1 + i2**) is assigned to the left-hand side (**sum**)
    - left-hand side is usually a variable
    - right-hand side is a simple or complex expression
  - Operator **+** specifies addition
    - left and right arguments are added
    - result is the sum of the two arguments
  - May other operators exist
    - For example, **-**, *****, **/**, **%**, **<**, **>**, **==**, **^**, **&**, **|**, ...

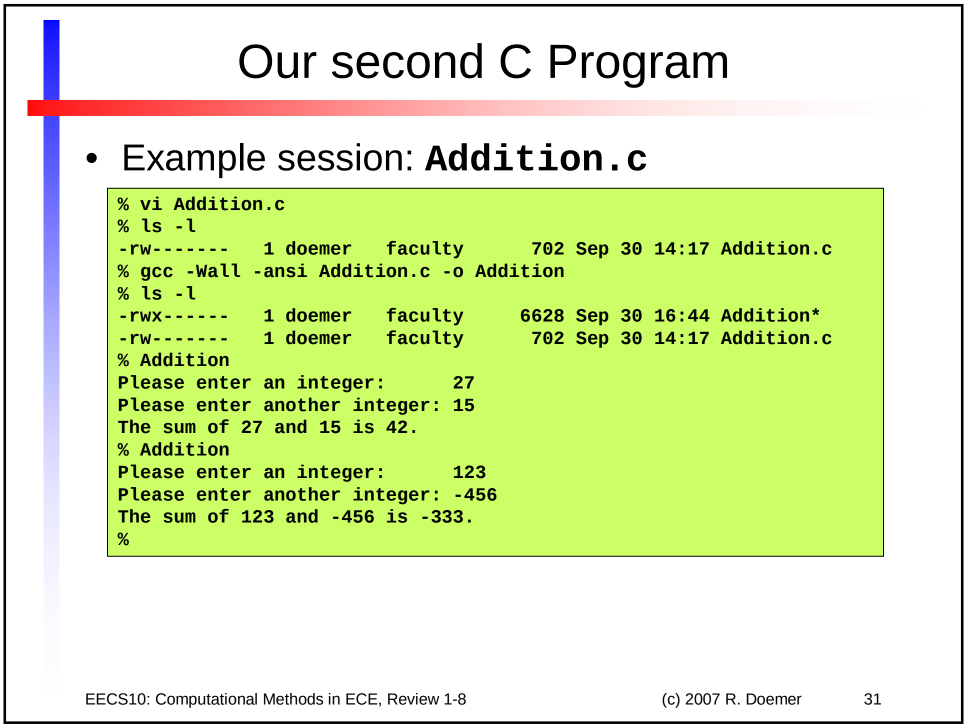


Our second C Program

- Data output using **printf()** function

```
/* output section */
printf("The sum of %d and %d is %d.\n", i1, i2, sum);
```

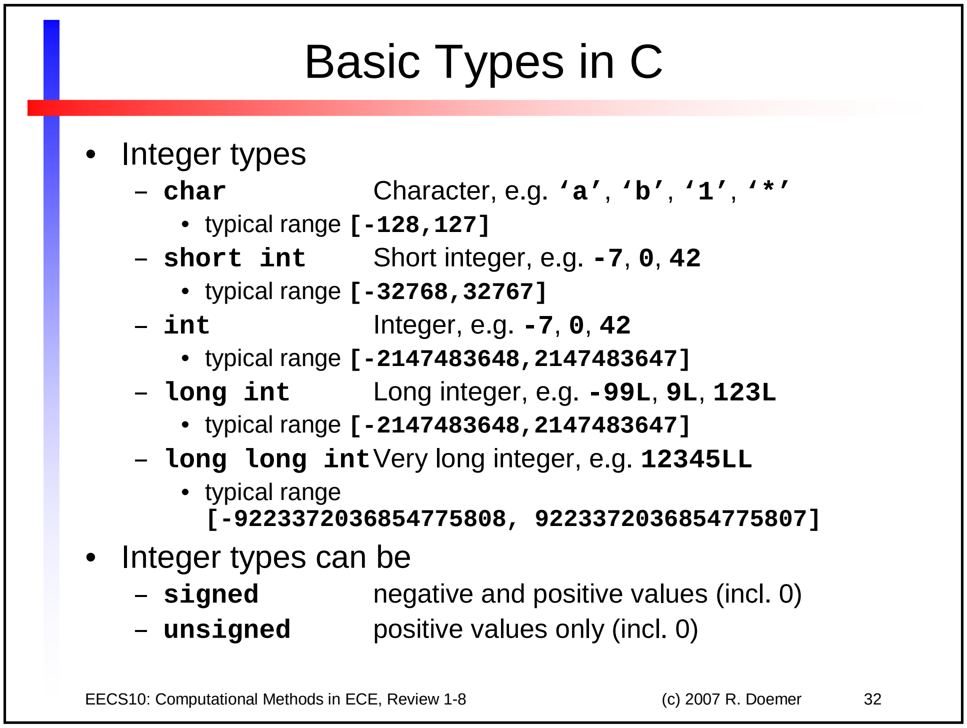
  - part of standard I/O library
    - declared in header file **stdio.h**
  - writes data to the standard output stream **stdout**
    - **stdout** usually means the monitor
  - converts output data according to format string
    - standard text is copied verbatim to the output
    - **“%d”** is replaced with a decimal integer value
  - takes values from specified arguments
    - **i1** indicates to use the value of the variable **i1**



Our second C Program

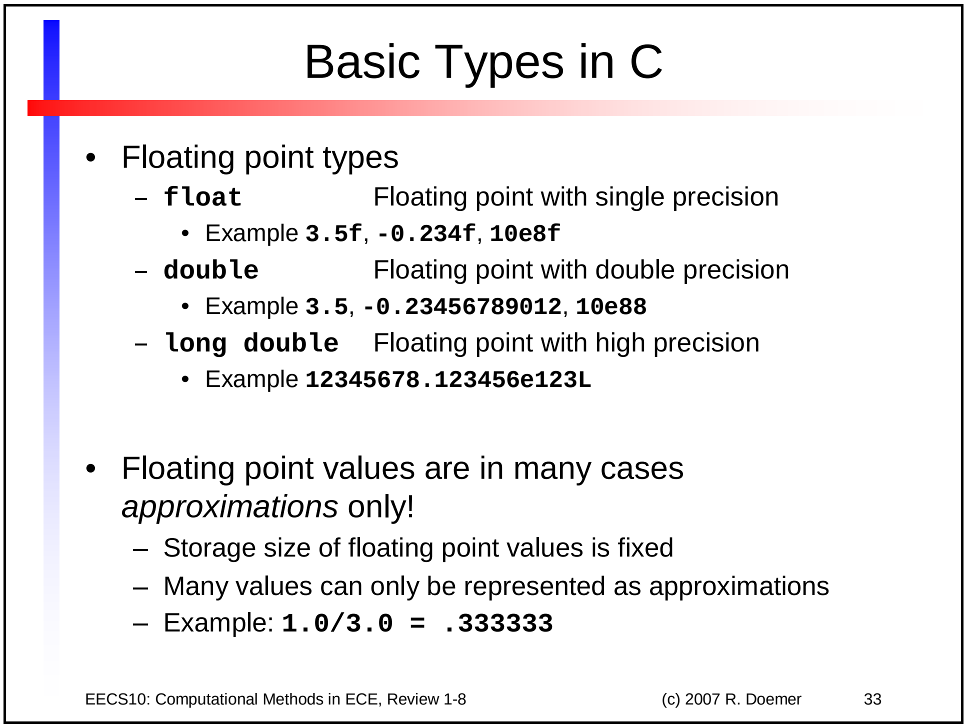
- Example session: **Addition.c**

```
% vi Addition.c
% ls -l
-rw-------   1 doemer   faculty      702 Sep 30 14:17 Addition.c
% gcc -Wall -ansi Addition.c -o Addition
% ls -l
-rwx------   1 doemer   faculty     6628 Sep 30 16:44 Addition*
-rw-------   1 doemer   faculty      702 Sep 30 14:17 Addition.c
% Addition
Please enter an integer:      27
Please enter another integer: 15
The sum of 27 and 15 is 42.
% Addition
Please enter an integer:      123
Please enter another integer: -456
The sum of 123 and -456 is -333.
%
```



Basic Types in C

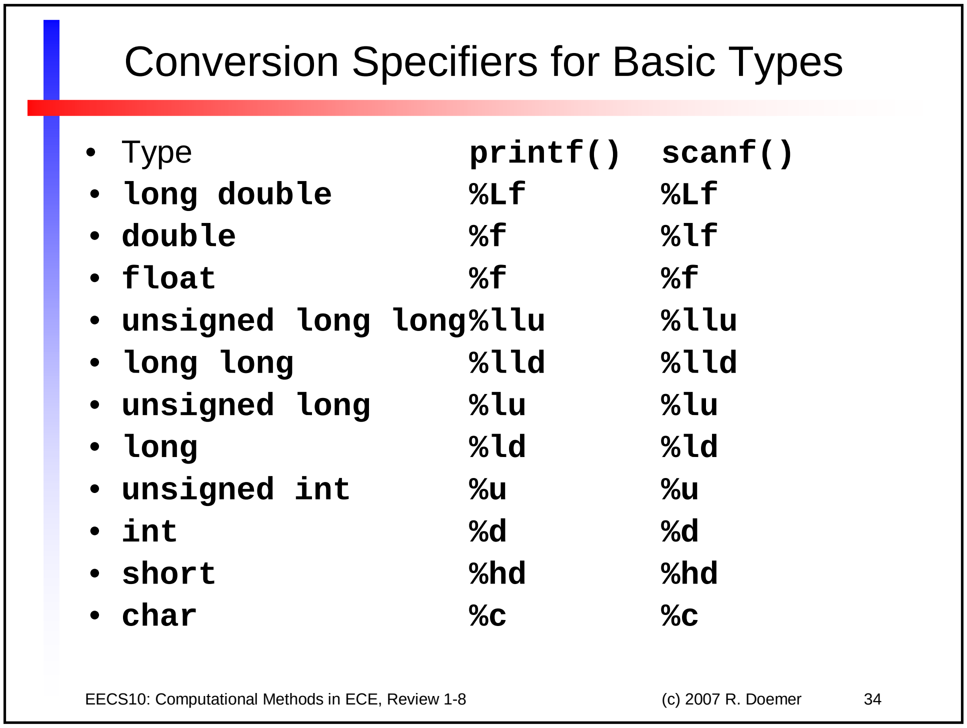
- Integer types
  - **char** Character, e.g. **'a'**, **'b'**, **'1'**, **'*'**
    - typical range **[-128,127]**
  - **short int** Short integer, e.g. **-7**, **0**, **42**
    - typical range **[-32768,32767]**
  - **int** Integer, e.g. **-7**, **0**, **42**
    - typical range **[-2147483648,2147483647]**
  - **long int** Long integer, e.g. **-99L**, **9L**, **123L**
    - typical range **[-2147483648,2147483647]**
  - **long long int** Very long integer, e.g. **12345LL**
    - typical range **[-9223372036854775808, 9223372036854775807]**
- Integer types can be
  - **signed** negative and positive values (incl. 0)
  - **unsigned** positive values only (incl. 0)



Basic Types in C

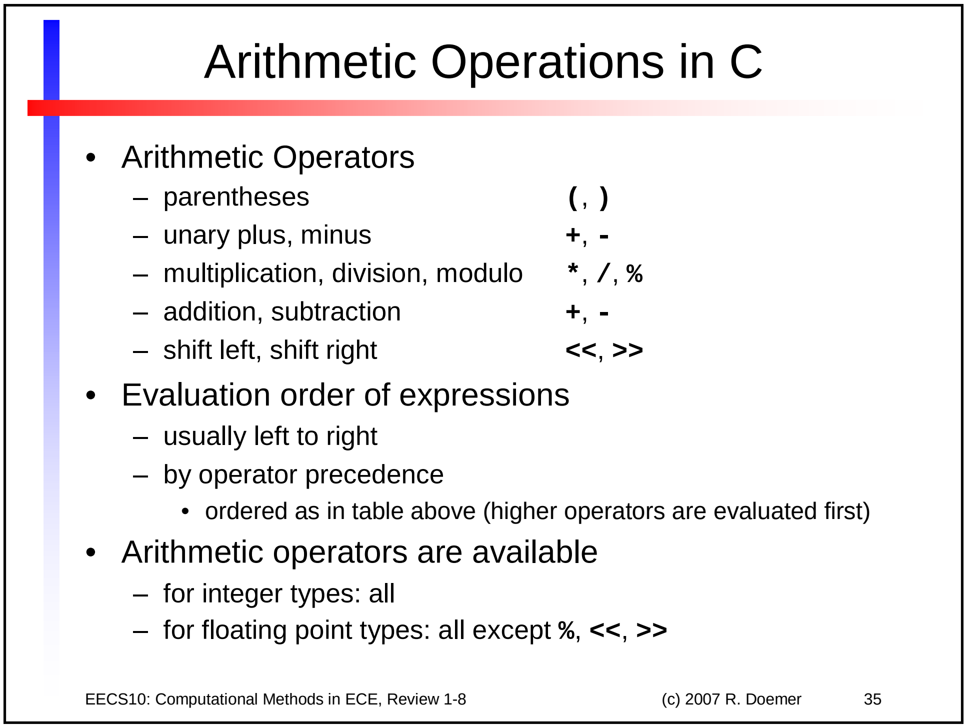
- Floating point types
  - **`float`** Floating point with single precision
    - Example **`3.5f`**, **`-0.234f`**, **`10e8f`**
  - **`double`** Floating point with double precision
    - Example **`3.5`**, **`-0.23456789012`**, **`10e88`**
  - **`long double`** Floating point with high precision
    - Example **`12345678.123456e123L`**

- Floating point values are in many cases *approximations* only!
  - Storage size of floating point values is fixed
  - Many values can only be represented as approximations
  - Example: **`1.0/3.0 = .333333`**



Conversion Specifiers for Basic Types

Type	**`printf()`**	**`scanf()`**
`long double`	**`%Lf`**	**`%Lf`**
`double`	**`%f`**	**`%lf`**
`float`	**`%f`**	**`%f`**
`unsigned long long`	**`%llu`**	**`%llu`**
`long long`	**`%lld`**	**`%lld`**
`unsigned long`	**`%lu`**	**`%lu`**
`long`	**`%ld`**	**`%ld`**
`unsigned int`	**`%u`**	**`%u`**
`int`	**`%d`**	**`%d`**
`short`	**`%hd`**	**`%hd`**
`char`	**`%c`**	**`%c`**



Arithmetic Operations in C

- Arithmetic Operators
  - parentheses **(**, **)**
  - unary plus, minus **+**, **-**
  - multiplication, division, modulo *****, **/**, **%**
  - addition, subtraction **+**, **-**
  - shift left, shift right **<<**, **>>**
- Evaluation order of expressions
  - usually left to right
  - by operator precedence
    - ordered as in table above (higher operators are evaluated first)
- Arithmetic operators are available
  - for integer types: all
  - for floating point types: all except **%**, **<<**, **>>**

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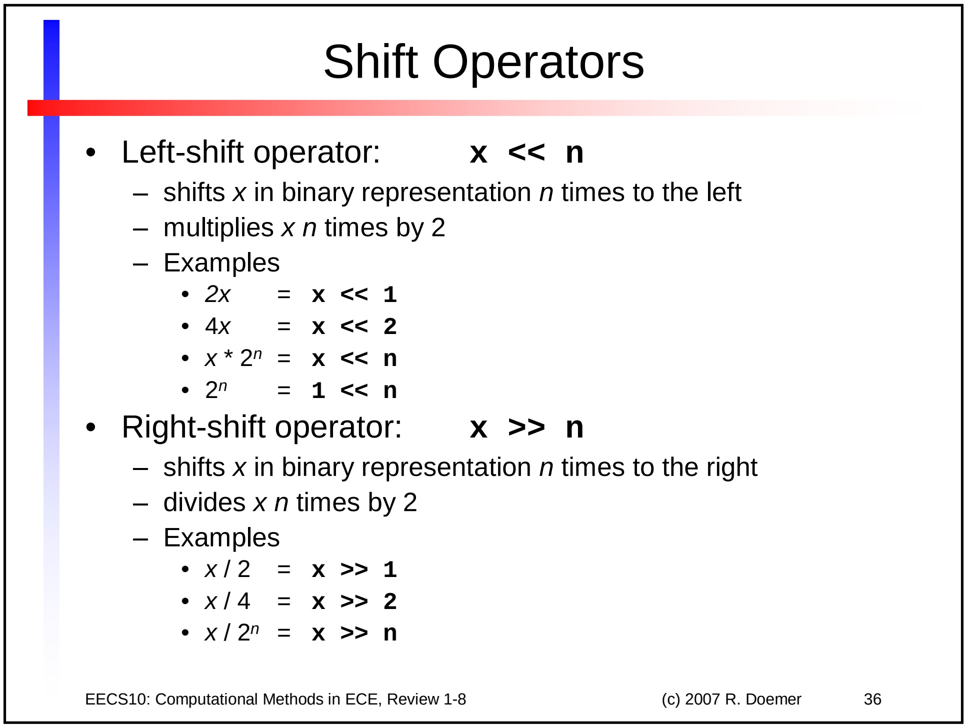

Shift Operators

- Left-shift operator: **x << n**
  - shifts *x* in binary representation *n* times to the left
  - multiplies *x* *n* times by 2
  - Examples
    - $2x$ = **x << 1**
    - $4x$ = **x << 2**
    - $x * 2^n$ = **x << n**
    - 2^n = **1 << n**
- Right-shift operator: **x >> n**
  - shifts *x* in binary representation *n* times to the right
  - divides *x* *n* times by 2
  - Examples
    - $x / 2$ = **x >> 1**
    - $x / 4$ = **x >> 2**
    - $x / 2^n$ = **x >> n**

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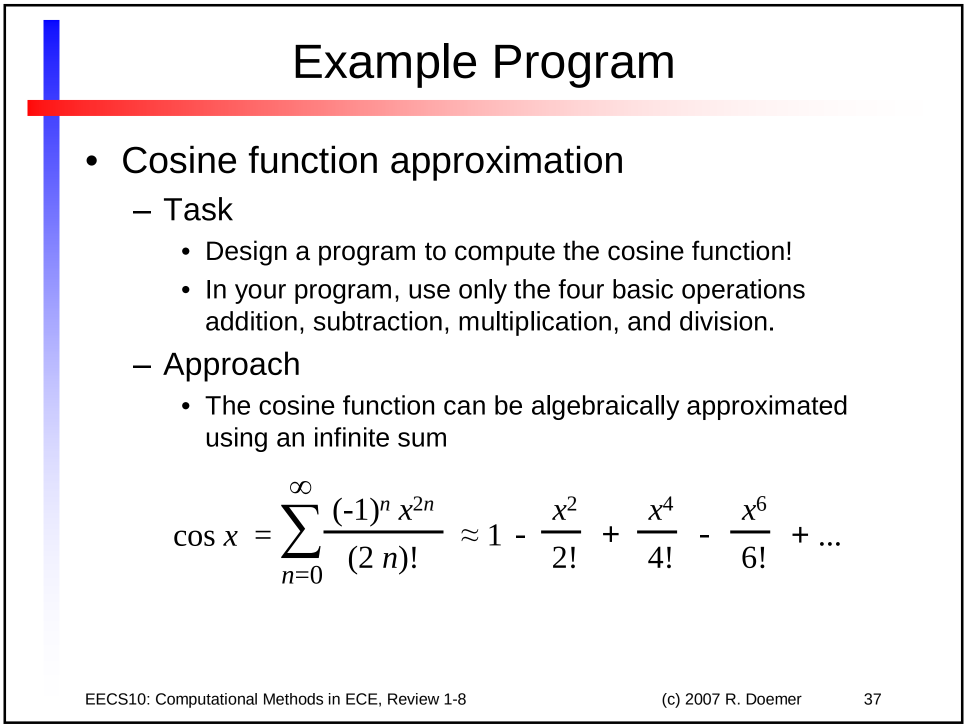
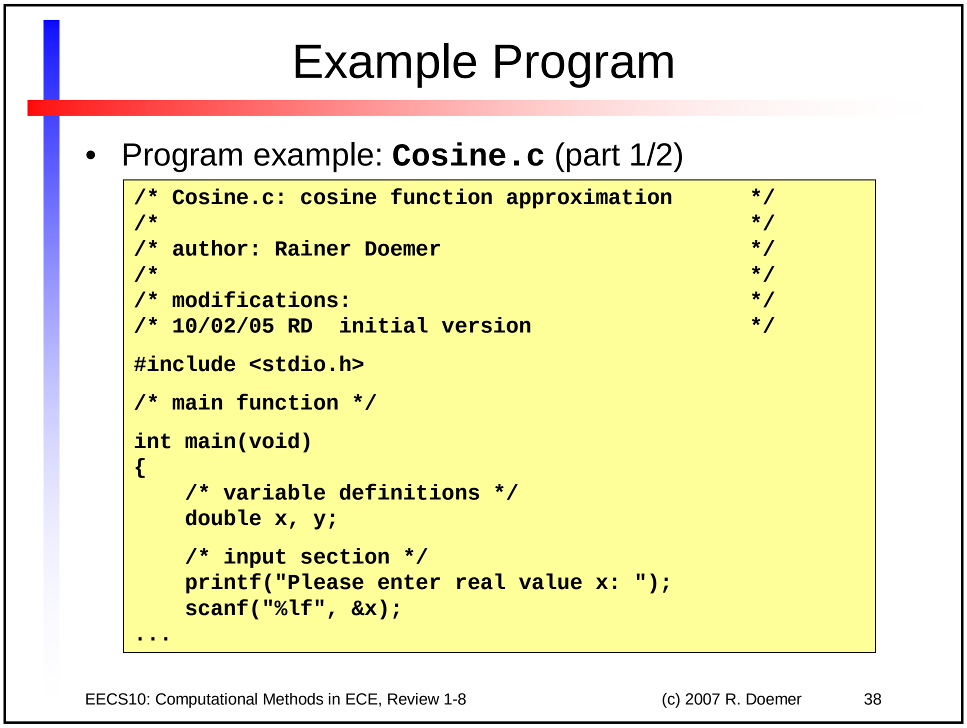


Example Program

- Cosine function approximation
  - Task
    - Design a program to compute the cosine function!
    - In your program, use only the four basic operations addition, subtraction, multiplication, and division.
  - Approach
    - The cosine function can be algebraically approximated using an infinite sum

$$\cos x = \sum_{n=0}^{\infty} \frac{(-1)^n x^{2n}}{(2\,n)!} \approx 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \frac{x^6}{6!} + \ldots$$



Example Program

- Program example: **`Cosine.c`** (part 1/2)

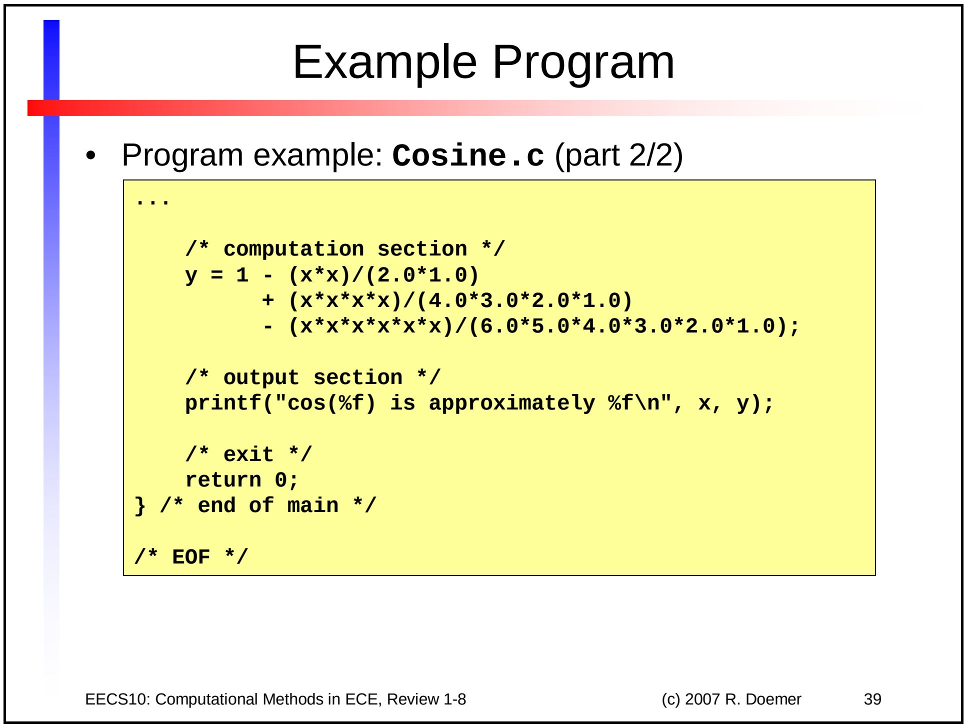
```
/* Cosine.c: cosine function approximation     */
/*                                             */
/* author: Rainer Doemer                       */
/*                                             */
/* modifications:                              */
/* 10/02/05 RD  initial version                */

#include <stdio.h>

/* main function */

int main(void)
{
    /* variable definitions */
    double x, y;

    /* input section */
    printf("Please enter real value x: ");
    scanf("%lf", &x);
...
```



Example Program

- Program example: **`Cosine.c`** (part 2/2)

```
...

    /* computation section */
    y = 1 - (x*x)/(2.0*1.0)
          + (x*x*x*x)/(4.0*3.0*2.0*1.0)
          - (x*x*x*x*x*x)/(6.0*5.0*4.0*3.0*2.0*1.0);

    /* output section */
    printf("cos(%f) is approximately %f\n", x, y);

    /* exit */
    return 0;
} /* end of main */

/* EOF */
```

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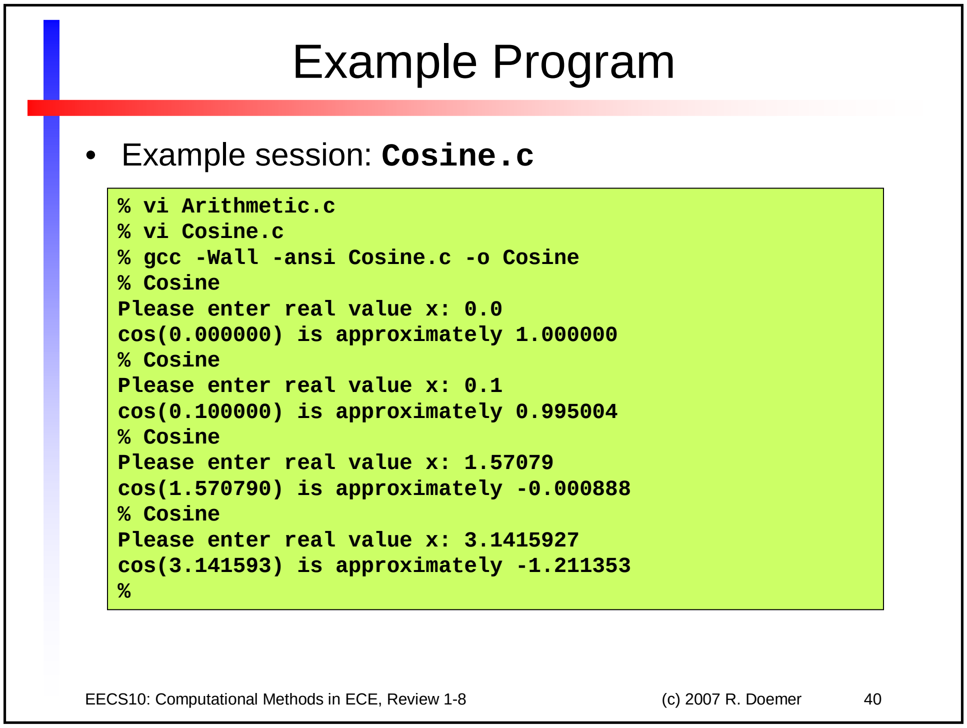

Example Program

- Example session: **`Cosine.c`**

```
% vi Arithmetic.c
% vi Cosine.c
% gcc -Wall -ansi Cosine.c -o Cosine
% Cosine
Please enter real value x: 0.0
cos(0.000000) is approximately 1.000000
% Cosine
Please enter real value x: 0.1
cos(0.100000) is approximately 0.995004
% Cosine
Please enter real value x: 1.57079
cos(1.570790) is approximately -0.000888
% Cosine
Please enter real value x: 3.1415927
cos(3.141593) is approximately -1.211353
%
```

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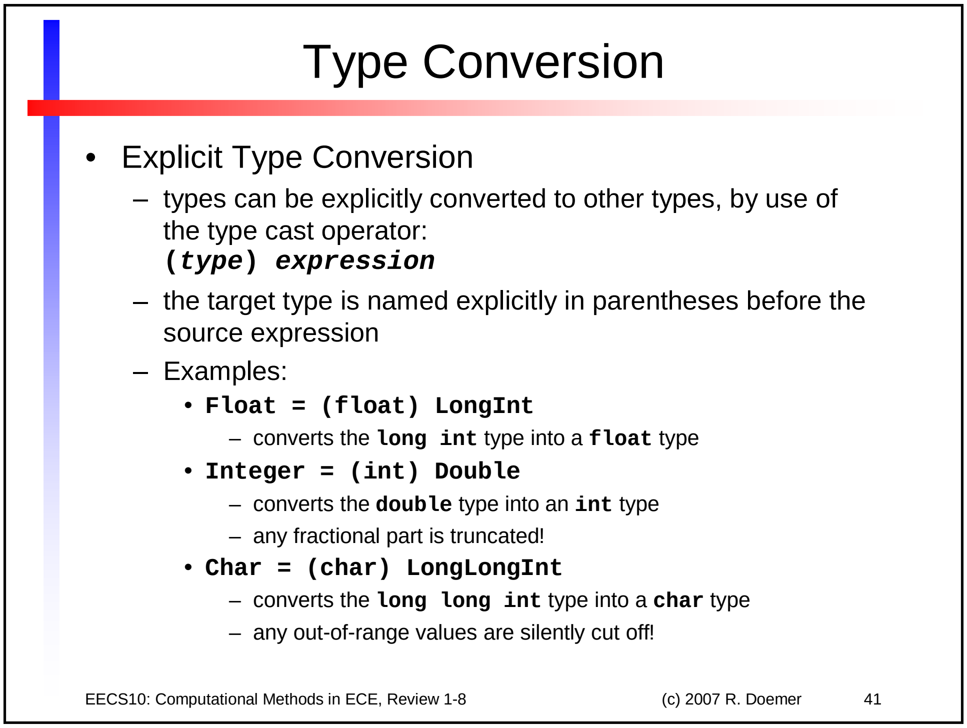
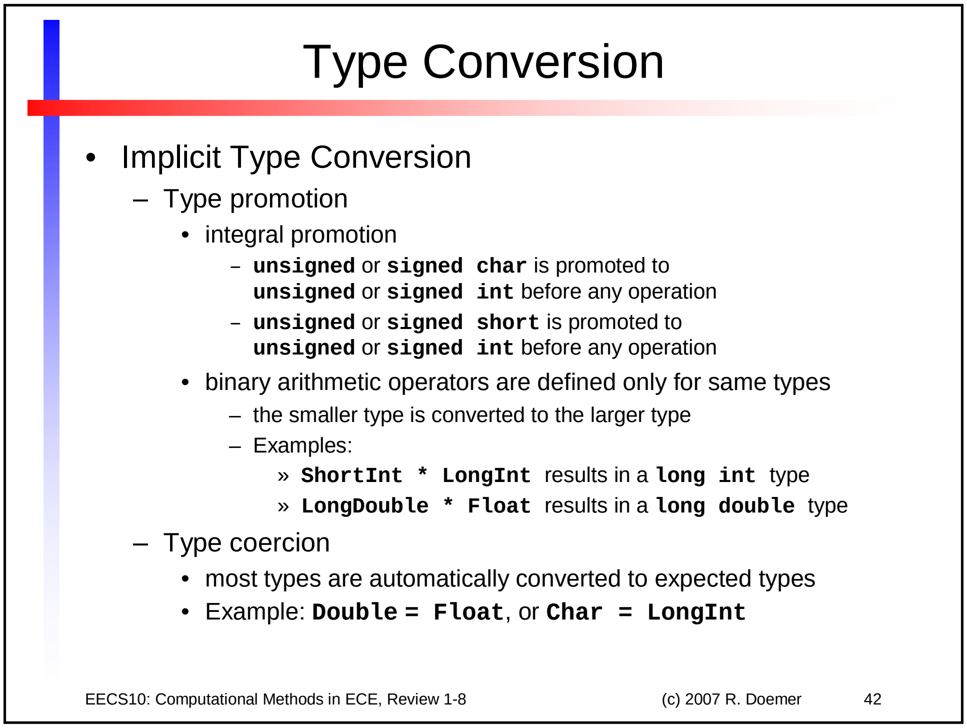


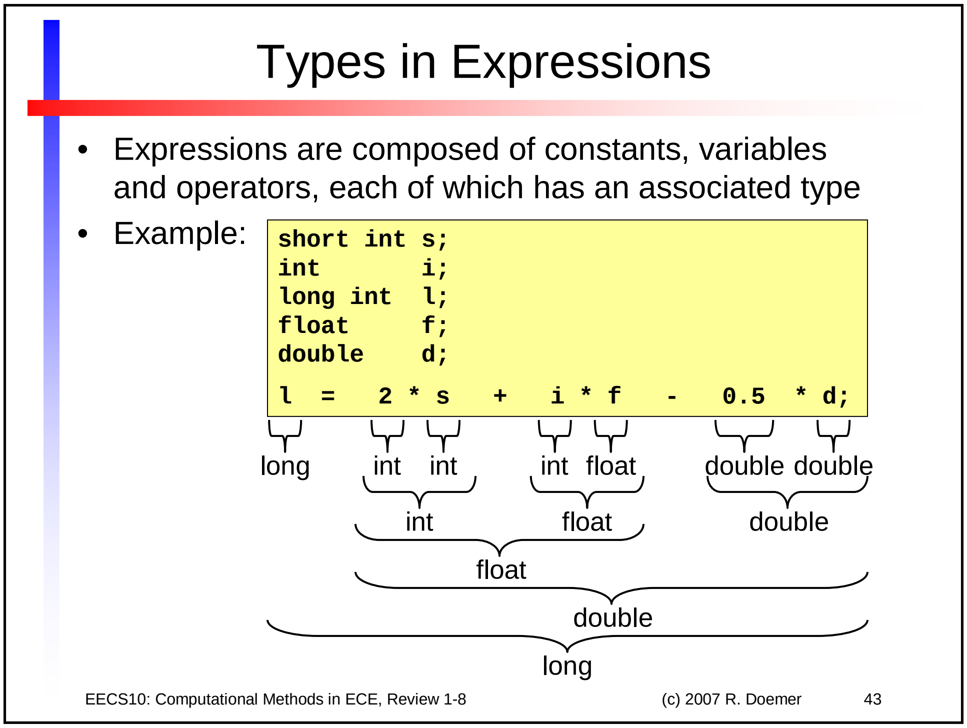
Type Conversion

- Explicit Type Conversion
  - types can be explicitly converted to other types, by use of the type cast operator:
    (type) expression
  - the target type is named explicitly in parentheses before the source expression
  - Examples:
    - **`Float = (float) LongInt`**
      - converts the **`long int`** type into a **`float`** type
    - **`Integer = (int) Double`**
      - converts the **`double`** type into an **`int`** type
      - any fractional part is truncated!
    - **`Char = (char) LongLongInt`**
      - converts the **`long long int`** type into a **`char`** type
      - any out-of-range values are silently cut off!



Type Conversion

- Implicit Type Conversion
  - Type promotion
    - integral promotion
      - **`unsigned`** or **`signed char`** is promoted to **`unsigned`** or **`signed int`** before any operation
      - **`unsigned`** or **`signed short`** is promoted to **`unsigned`** or **`signed int`** before any operation
    - binary arithmetic operators are defined only for same types
      - the smaller type is converted to the larger type
      - Examples:
        » **`ShortInt * LongInt`** results in a **`long int`** type
        » **`LongDouble * Float`** results in a **`long double`** type
  - Type coercion
    - most types are automatically converted to expected types
    - Example: **`Double = Float`**, or **`Char = LongInt`**



Types in Expressions

- Expressions are composed of constants, variables and operators, each of which has an associated type
- Example:

```
short int s;
int       i;
long int  l;
float     f;
double    d;

l  =   2 * s   +   i * f   -   0.5  * d;
```

$$\underbrace{\underbrace{l}_{\text{long}} = \underbrace{\underbrace{\underbrace{\underbrace{2}_{\text{int}} * \underbrace{s}_{\text{int}}}_{\text{int}} + \underbrace{\underbrace{i}_{\text{int}} * \underbrace{f}_{\text{float}}}_{\text{float}}}_{\text{float}} - \underbrace{\underbrace{0.5}_{\text{double}} * \underbrace{d}_{\text{double}}}_{\text{double}}}_{\text{double}}}_{\text{long}}$$

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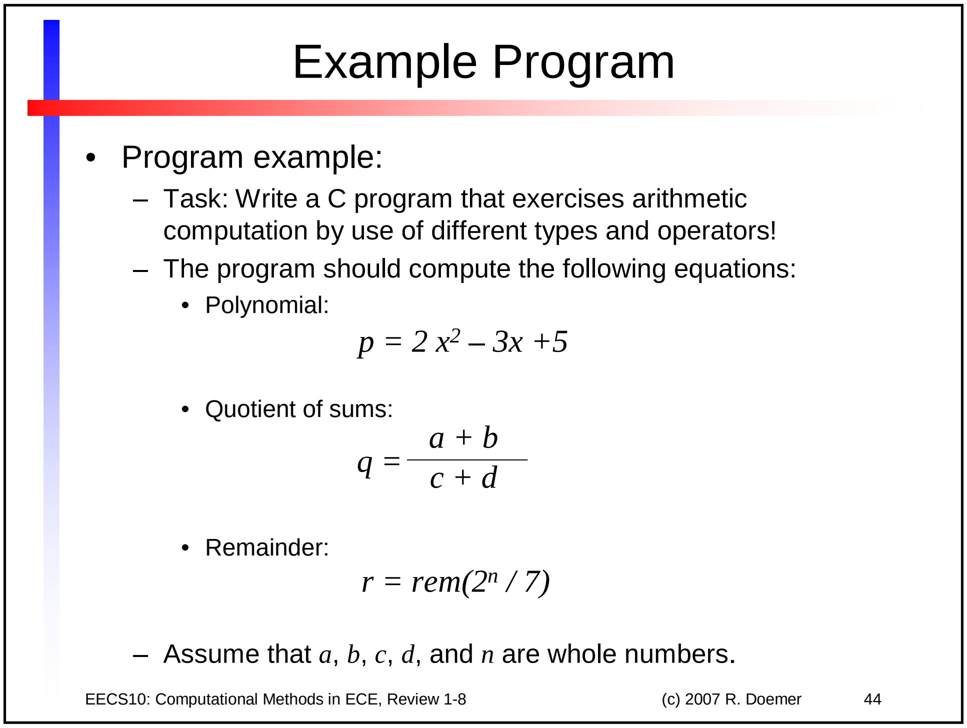

Example Program

- Program example:
  - Task: Write a C program that exercises arithmetic computation by use of different types and operators!
  - The program should compute the following equations:
    - Polynomial:

$$p = 2\,x^2 - 3x + 5$$

    - Quotient of sums:

$$q = \frac{a + b}{c + d}$$

    - Remainder:

$$r = rem(2^n / 7)$$

  - Assume that a, b, c, d, and n are whole numbers.

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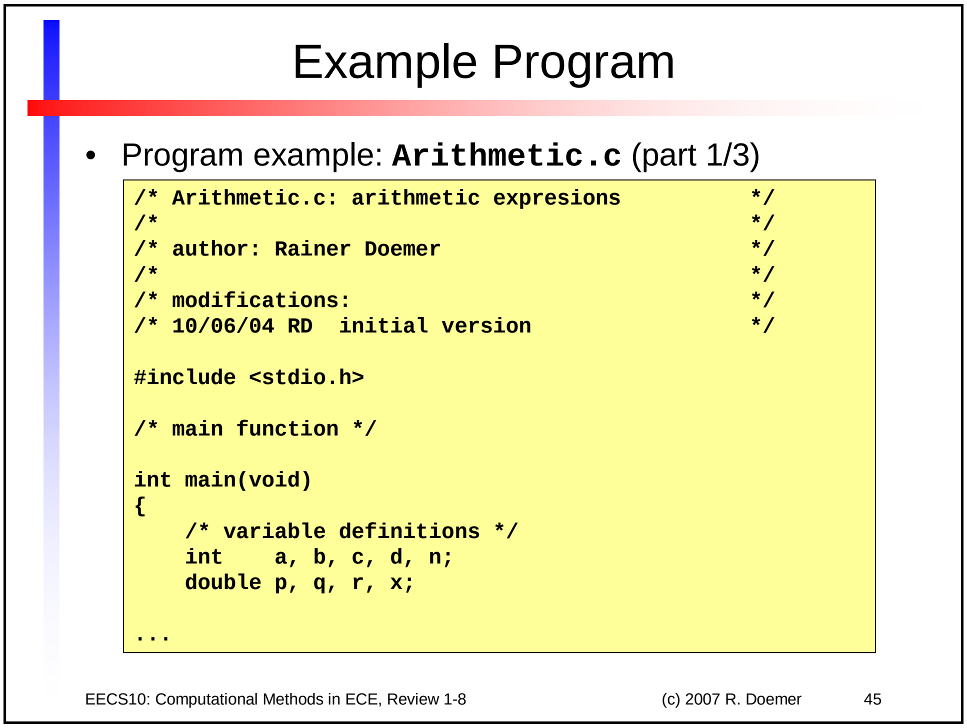

Example Program

- Program example: **`Arithmetic.c`** (part 1/3)

```
/* Arithmetic.c: arithmetic expresions          */
/*                                              */
/* author: Rainer Doemer                        */
/*                                              */
/* modifications:                               */
/* 10/06/04 RD  initial version                 */

#include <stdio.h>

/* main function */

int main(void)
{
    /* variable definitions */
    int    a, b, c, d, n;
    double p, q, r, x;

...
```

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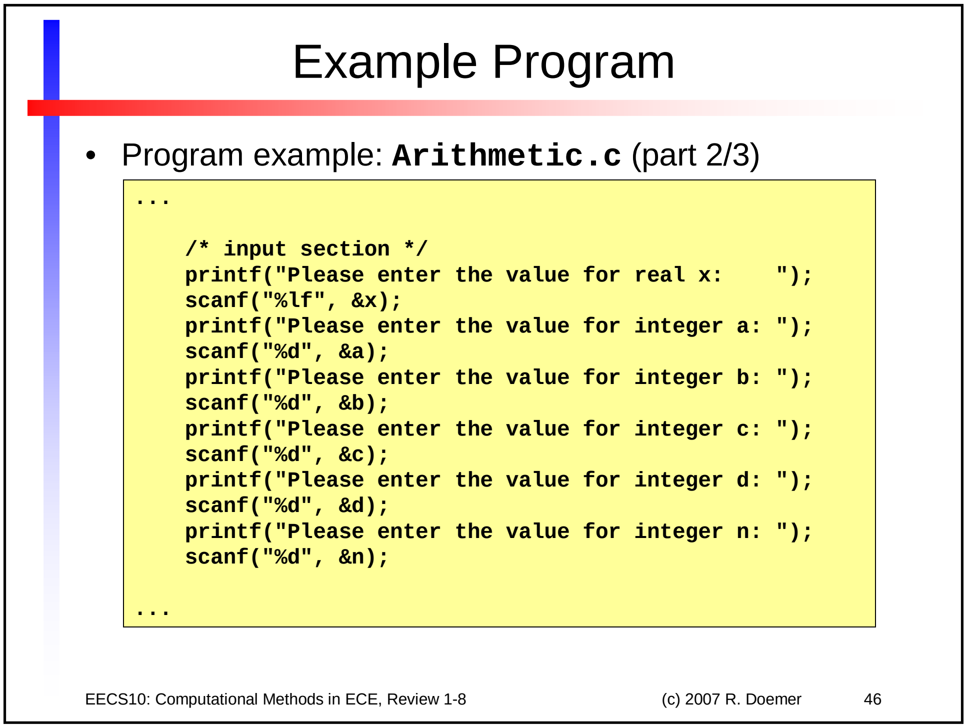

Example Program

- Program example: **`Arithmetic.c`** (part 2/3)

```
...

    /* input section */
    printf("Please enter the value for real x:    ");
    scanf("%lf", &x);
    printf("Please enter the value for integer a: ");
    scanf("%d", &a);
    printf("Please enter the value for integer b: ");
    scanf("%d", &b);
    printf("Please enter the value for integer c: ");
    scanf("%d", &c);
    printf("Please enter the value for integer d: ");
    scanf("%d", &d);
    printf("Please enter the value for integer n: ");
    scanf("%d", &n);

...
```

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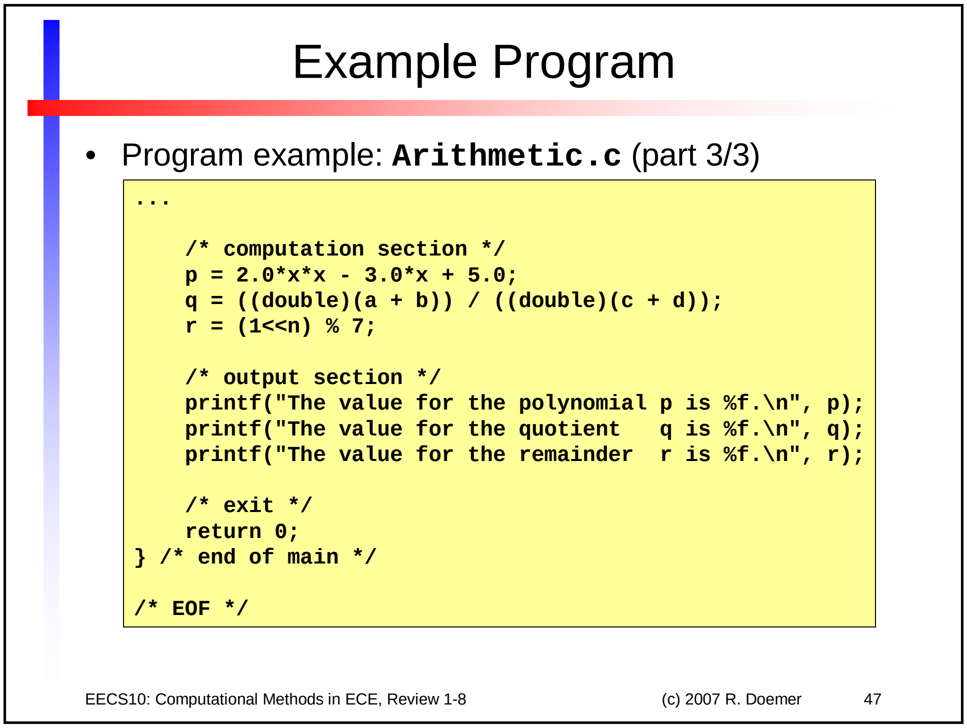


Example Program

- Program example: **`Arithmetic.c`** (part 3/3)

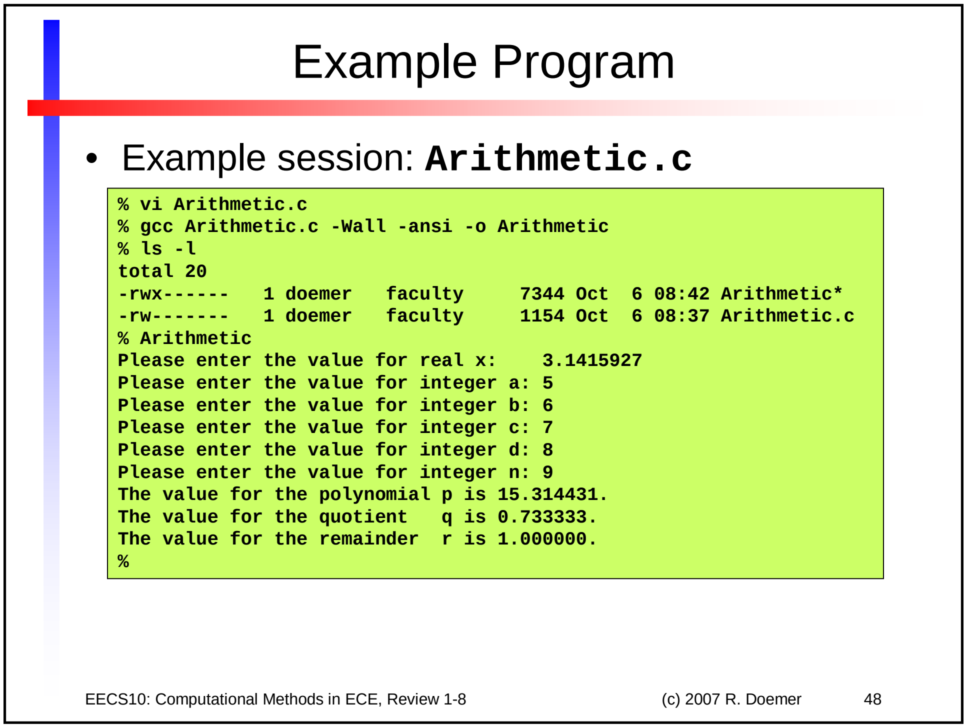
```
...

    /* computation section */
    p = 2.0*x*x - 3.0*x + 5.0;
    q = ((double)(a + b)) / ((double)(c + d));
    r = (1<<n) % 7;

    /* output section */
    printf("The value for the polynomial p is %f.\n", p);
    printf("The value for the quotient   q is %f.\n", q);
    printf("The value for the remainder  r is %f.\n", r);

    /* exit */
    return 0;
} /* end of main */

/* EOF */
```



Example Program

- Example session: **`Arithmetic.c`**

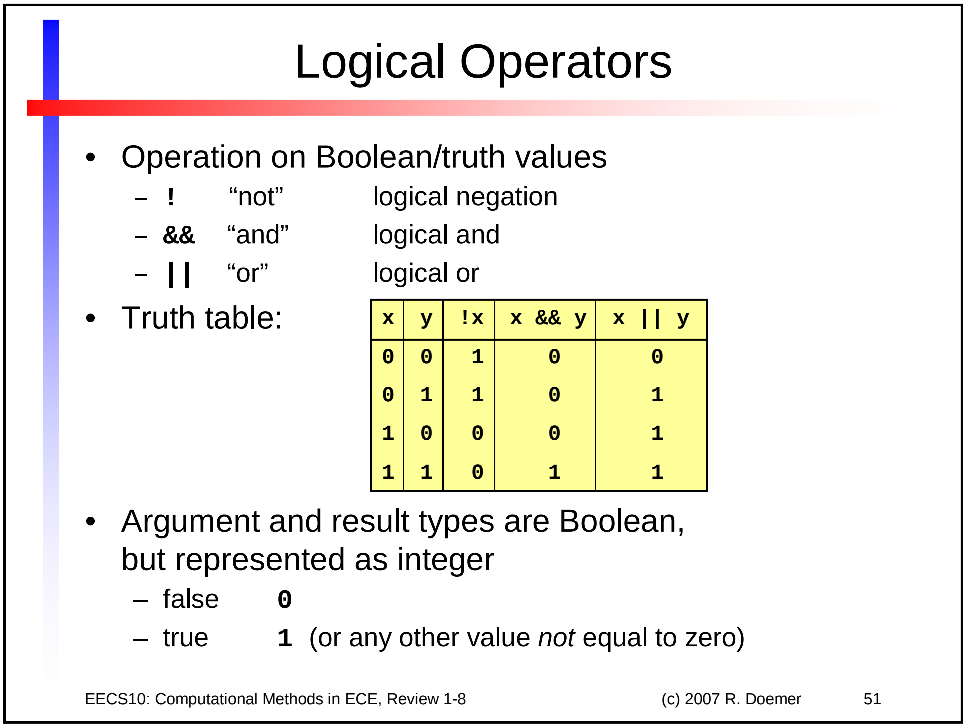
```
% vi Arithmetic.c
% gcc Arithmetic.c -Wall -ansi -o Arithmetic
% ls -l
total 20
-rwx------   1 doemer   faculty     7344 Oct  6 08:42 Arithmetic*
-rw-------   1 doemer   faculty     1154 Oct  6 08:37 Arithmetic.c
% Arithmetic
Please enter the value for real x:    3.1415927
Please enter the value for integer a: 5
Please enter the value for integer b: 6
Please enter the value for integer c: 7
Please enter the value for integer d: 8
Please enter the value for integer n: 9
The value for the polynomial p is 15.314431.
The value for the quotient   q is 0.733333.
The value for the remainder  r is 1.000000.
%
```

Comparison of Values

- Relational Operators
  - direct comparison of two values
  - Boolean result: truth value, true or false
- Logical Operators
  - Operations on Boolean values
- Conditional Operator
  - Conditional evaluation of expressions

Relational Operators

- Comparison operations
  - **`<`** less than
  - **`>`** greater than
  - **`<=`** less than or equal to
  - **`>=`** greater than or equal to
  - **`==`** equal to (remember, **`=`** means assignment!)
  - **`!=`** not equal to
- Comparison is defined for all basic types
  - integer (e.g. **`5 < 6`**)
  - floating point (e.g. **`7.0 < 7e1`**)
- Result type is Boolean, but represented as integer
  - false **`0`**
  - true **`1 (`**or any other value *not* equal to zero**`)`**



Logical Operators

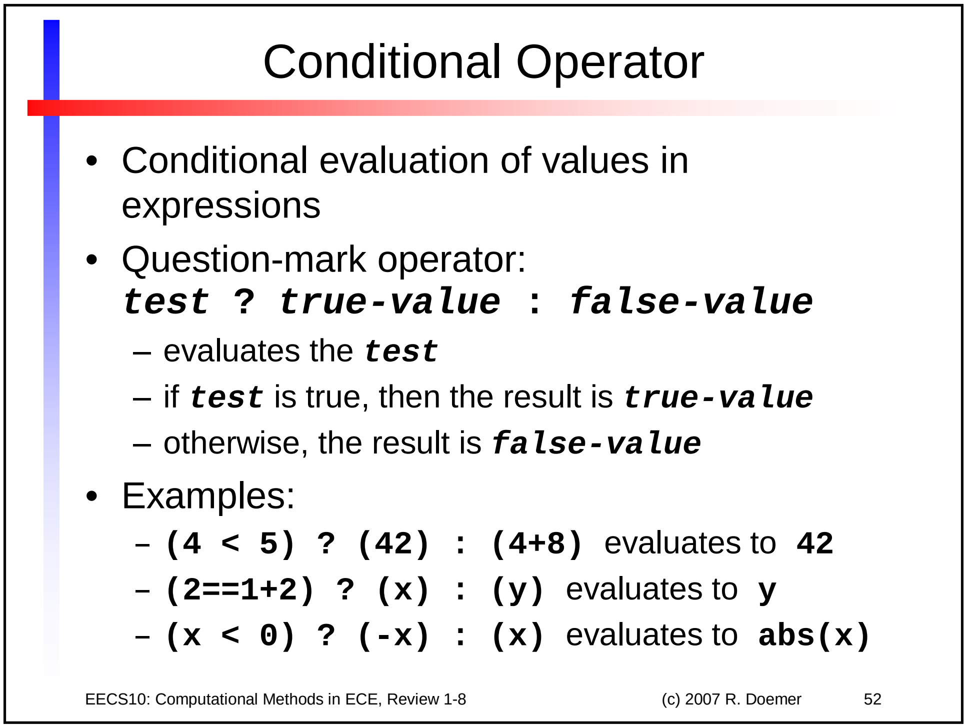
- Operation on Boolean/truth values

– **!**	“not”	logical negation
– **&&**	“and”	logical and
– **||**	“or”	logical or

- Truth table:

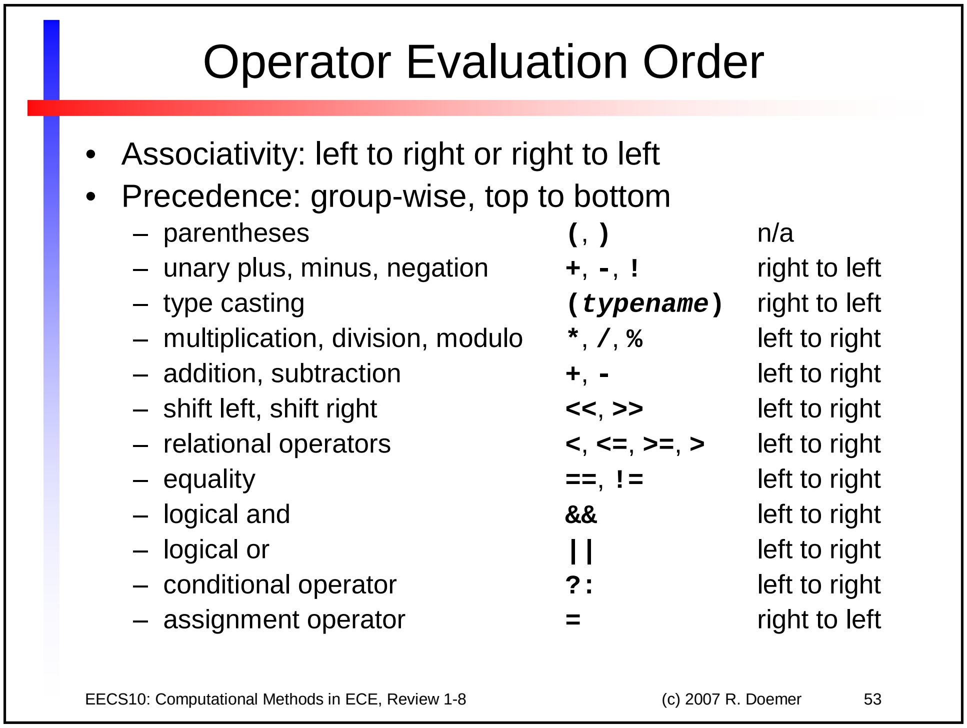
x	y	!x	x && y	x || y
0	0	1	0	0
0	1	1	0	1
1	0	0	0	1
1	1	0	1	1

- Argument and result types are Boolean, but represented as integer
  - false **0**
  - true **1** (or any other value *not* equal to zero)



Conditional Operator

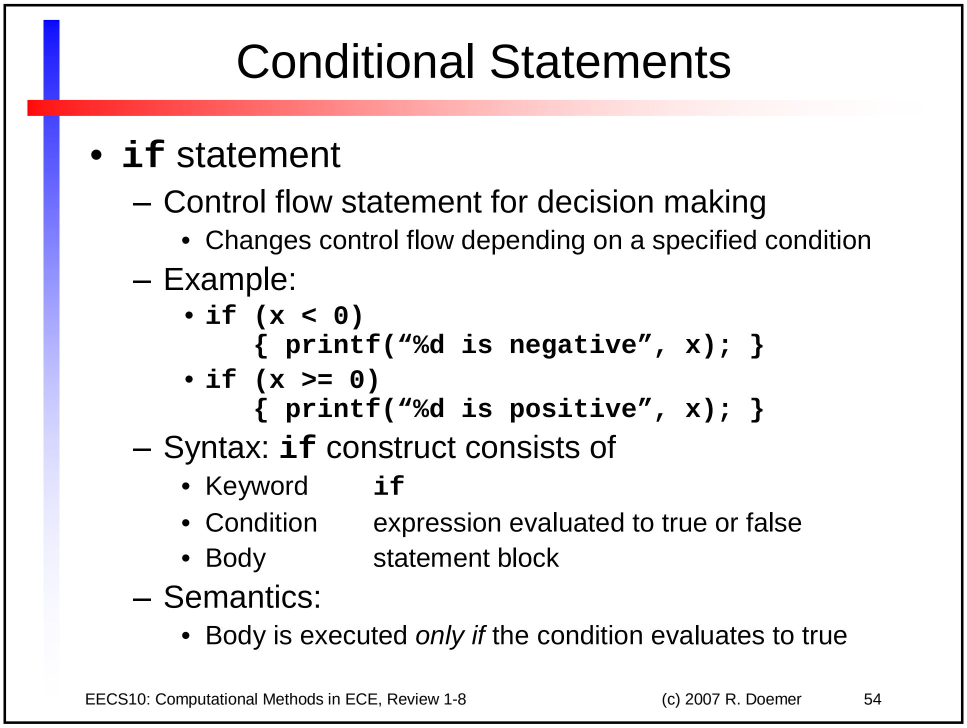
- Conditional evaluation of values in expressions
- Question-mark operator:
  test ? true-value : false-value
  - evaluates the ***test***
  - if ***test*** is true, then the result is ***true-value***
  - otherwise, the result is ***false-value***
- Examples:
  - **(4 < 5) ? (42) : (4+8)** evaluates to **42**
  - **(2==1+2) ? (x) : (y)** evaluates to **y**
  - **(x < 0) ? (-x) : (x)** evaluates to **abs(x)**



Operator Evaluation Order

- Associativity: left to right or right to left
- Precedence: group-wise, top to bottom

– parentheses	**(**, **)**	n/a
– unary plus, minus, negation	**+**, **-**, **!**	right to left
– type casting	**(*typename*)**	right to left
– multiplication, division, modulo	*****, **/**, **%**	left to right
– addition, subtraction	**+**, **-**	left to right
– shift left, shift right	**<<**, **>>**	left to right
– relational operators	**<**, **<=**, **>=**, **>**	left to right
– equality	**==**, **!=**	left to right
– logical and	**&&**	left to right
– logical or	**||**	left to right
– conditional operator	**?:**	left to right
– assignment operator	**=**	right to left



Conditional Statements

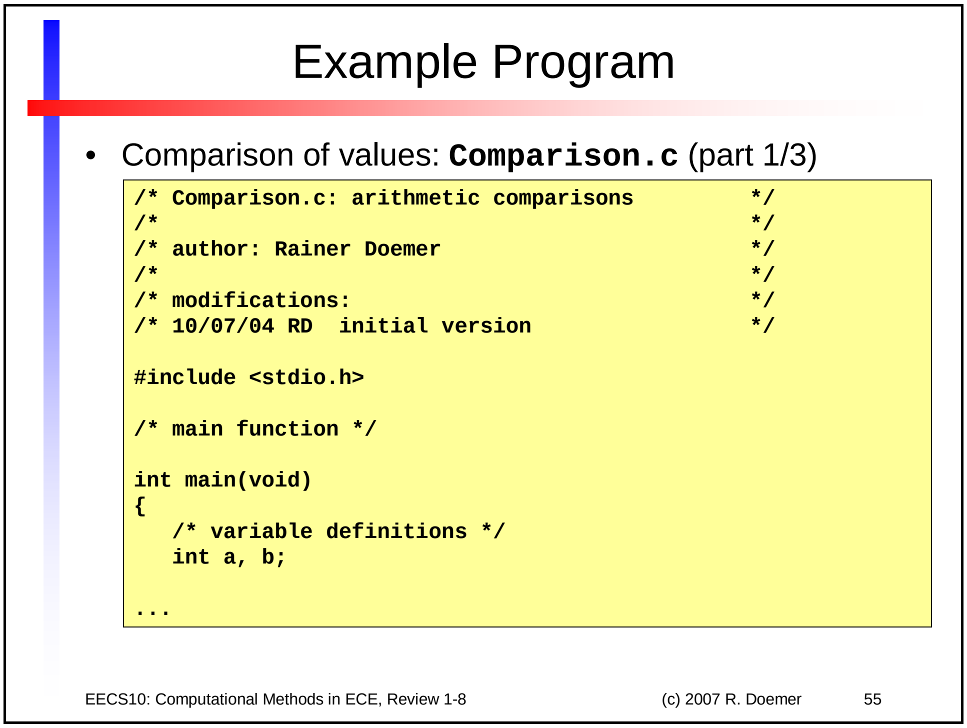
- **`if`** statement
  - Control flow statement for decision making
    - Changes control flow depending on a specified condition
  - Example:

```
• if (x < 0)
     { printf(“%d is negative”, x); }
• if (x >= 0)
     { printf(“%d is positive”, x); }
```

  - Syntax: **`if`** construct consists of

• Keyword	**`if`**
• Condition	expression evaluated to true or false
• Body	statement block

  - Semantics:
    - Body is executed *only if* the condition evaluates to true



Example Program

- Comparison of values: **`Comparison.c`** (part 1/3)

```
/* Comparison.c: arithmetic comparisons         */
/*                                              */
/* author: Rainer Doemer                        */
/*                                              */
/* modifications:                               */
/* 10/07/04 RD  initial version                 */

#include <stdio.h>

/* main function */

int main(void)
{
   /* variable definitions */
   int a, b;

...
```

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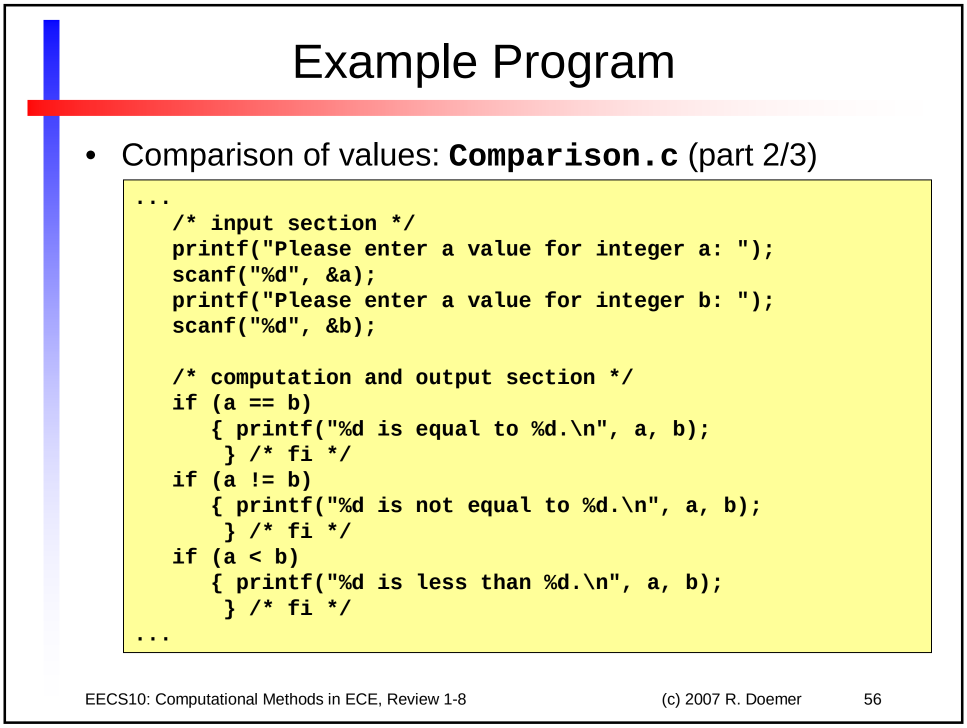

Example Program

- Comparison of values: **`Comparison.c`** (part 2/3)

```
...
   /* input section */
   printf("Please enter a value for integer a: ");
   scanf("%d", &a);
   printf("Please enter a value for integer b: ");
   scanf("%d", &b);

   /* computation and output section */
   if (a == b)
      { printf("%d is equal to %d.\n", a, b);
       } /* fi */
   if (a != b)
      { printf("%d is not equal to %d.\n", a, b);
       } /* fi */
   if (a < b)
      { printf("%d is less than %d.\n", a, b);
       } /* fi */
...
```

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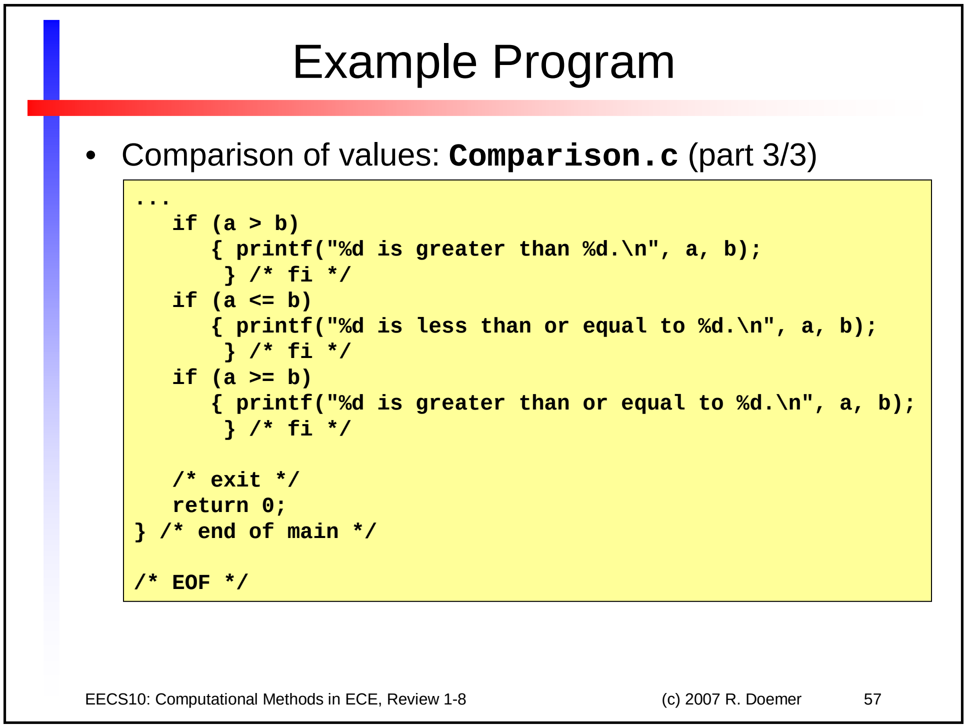
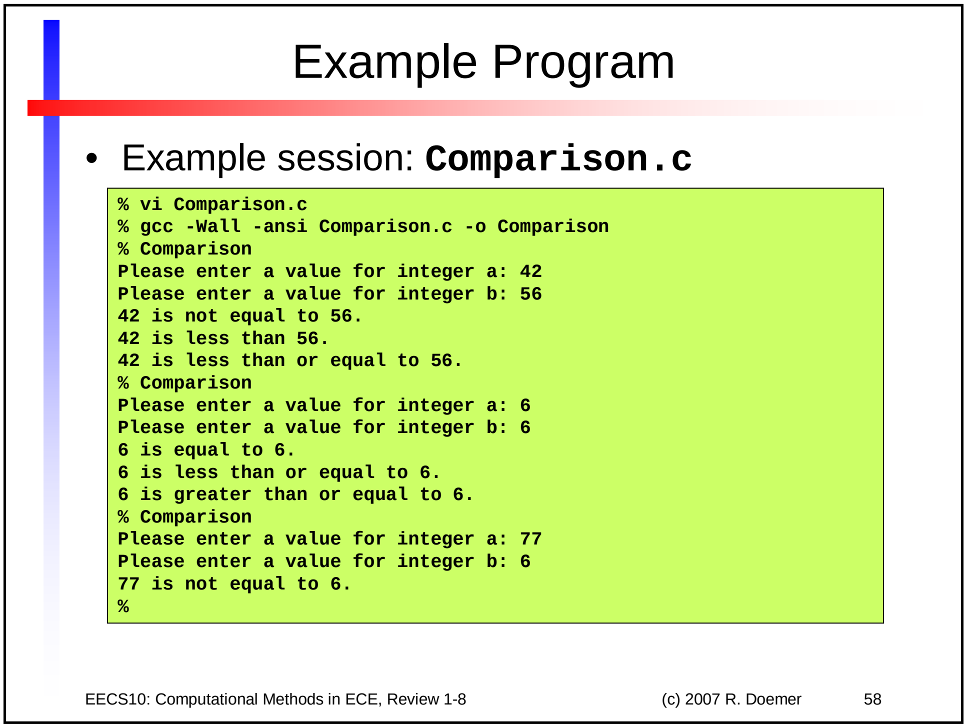


Example Program

- Comparison of values: **`Comparison.c`** (part 3/3)

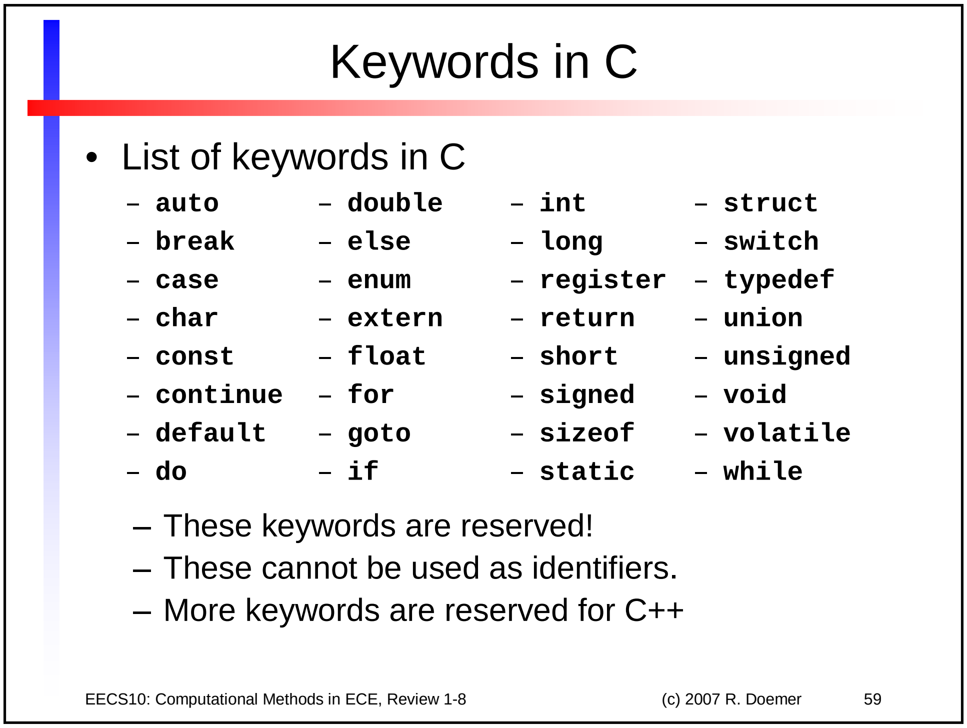
```
...
   if (a > b)
      { printf("%d is greater than %d.\n", a, b);
       } /* fi */
   if (a <= b)
      { printf("%d is less than or equal to %d.\n", a, b);
       } /* fi */
   if (a >= b)
      { printf("%d is greater than or equal to %d.\n", a, b);
       } /* fi */

   /* exit */
   return 0;
} /* end of main */

/* EOF */
```



Example Program

- Example session: **`Comparison.c`**

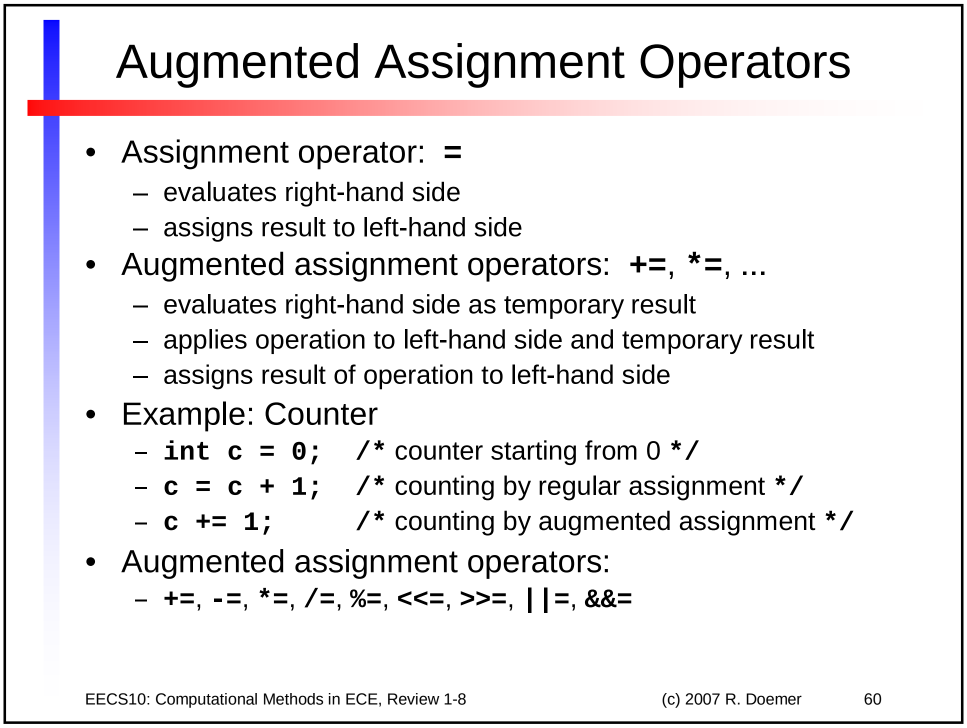
```
% vi Comparison.c
% gcc -Wall -ansi Comparison.c -o Comparison
% Comparison
Please enter a value for integer a: 42
Please enter a value for integer b: 56
42 is not equal to 56.
42 is less than 56.
42 is less than or equal to 56.
% Comparison
Please enter a value for integer a: 6
Please enter a value for integer b: 6
6 is equal to 6.
6 is less than or equal to 6.
6 is greater than or equal to 6.
% Comparison
Please enter a value for integer a: 77
Please enter a value for integer b: 6
77 is not equal to 6.
%
```



Keywords in C

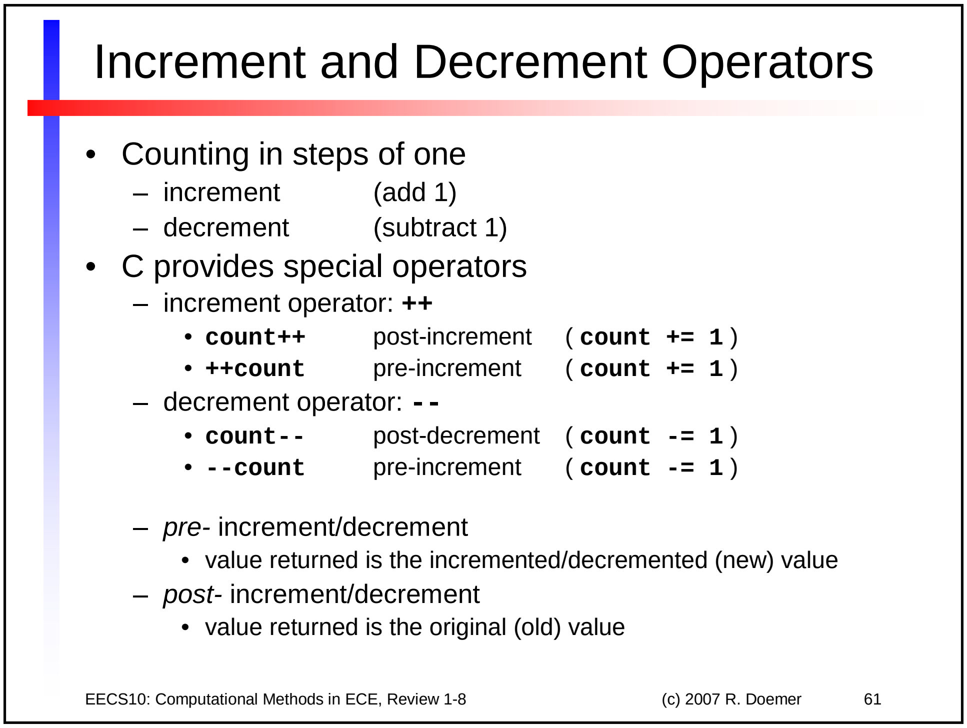
- List of keywords in C
  - auto
  - break
  - case
  - char
  - const
  - continue
  - default
  - do
  - double
  - else
  - enum
  - extern
  - float
  - for
  - goto
  - if
  - int
  - long
  - register
  - return
  - short
  - signed
  - sizeof
  - static
  - struct
  - switch
  - typedef
  - union
  - unsigned
  - void
  - volatile
  - while

  - These keywords are reserved!
  - These cannot be used as identifiers.
  - More keywords are reserved for C++



Augmented Assignment Operators

- Assignment operator: **=**
  - evaluates right-hand side
  - assigns result to left-hand side
- Augmented assignment operators: **+=**, ***=**, ...
  - evaluates right-hand side as temporary result
  - applies operation to left-hand side and temporary result
  - assigns result of operation to left-hand side
- Example: Counter
  - **int c = 0;** /* counter starting from 0 */
  - **c = c + 1;** /* counting by regular assignment */
  - **c += 1;** /* counting by augmented assignment */
- Augmented assignment operators:
  - **+=**, **-=**, ***=**, **/=**, **%=**, **<<=**, **>>=**, **||=**, **&&=**



Increment and Decrement Operators

- Counting in steps of one
  - increment (add 1)
  - decrement (subtract 1)
- C provides special operators
  - increment operator: **`++`**
    - **`count++`** post-increment (**`count += 1`**)
    - **`++count`** pre-increment (**`count += 1`**)
  - decrement operator: **`--`**
    - **`count--`** post-decrement (**`count -= 1`**)
    - **`--count`** pre-increment (**`count -= 1`**)

  - *pre*- increment/decrement
    - value returned is the incremented/decremented (new) value
  - *post*- increment/decrement
    - value returned is the original (old) value

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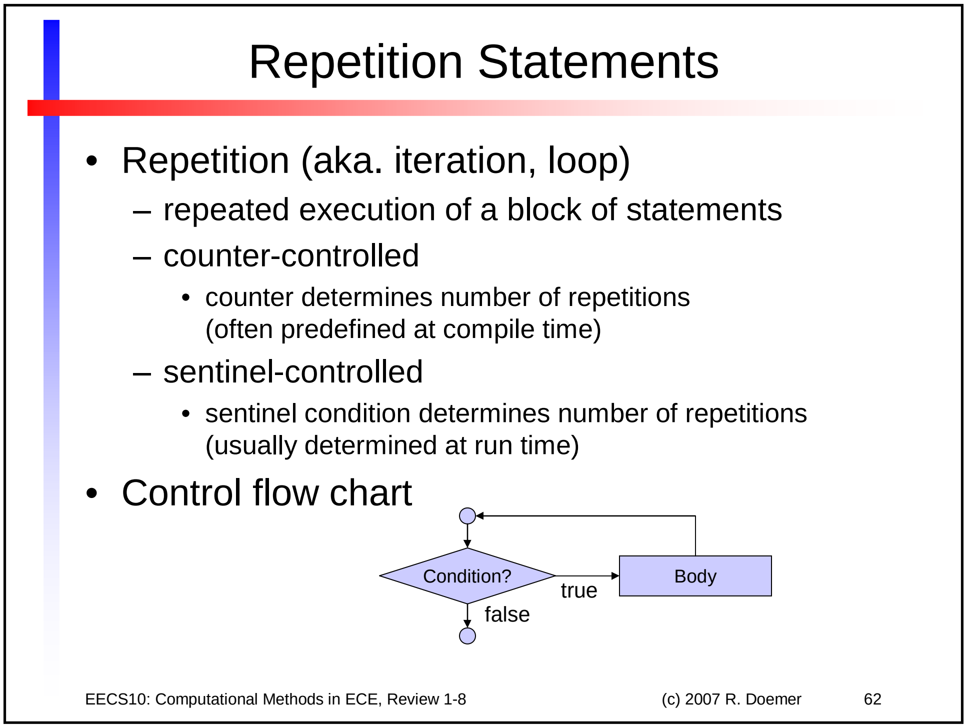

Repetition Statements

- Repetition (aka. iteration, loop)
  - repeated execution of a block of statements
  - counter-controlled
    - counter determines number of repetitions (often predefined at compile time)
  - sentinel-controlled
    - sentinel condition determines number of repetitions (usually determined at run time)
- Control flow chart

Condition?
true
Body
false

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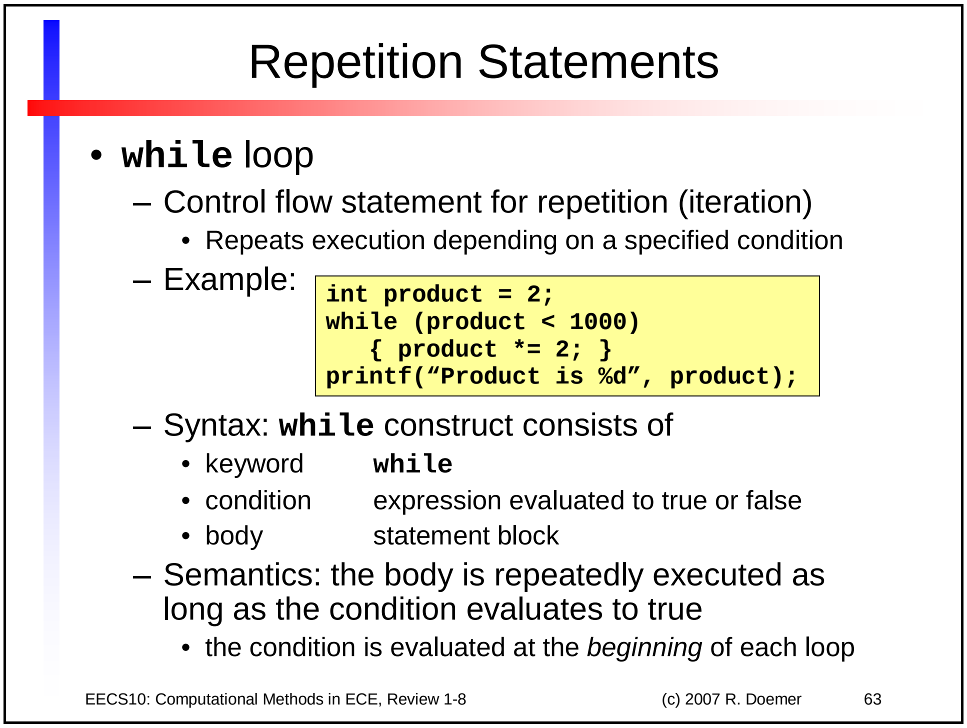
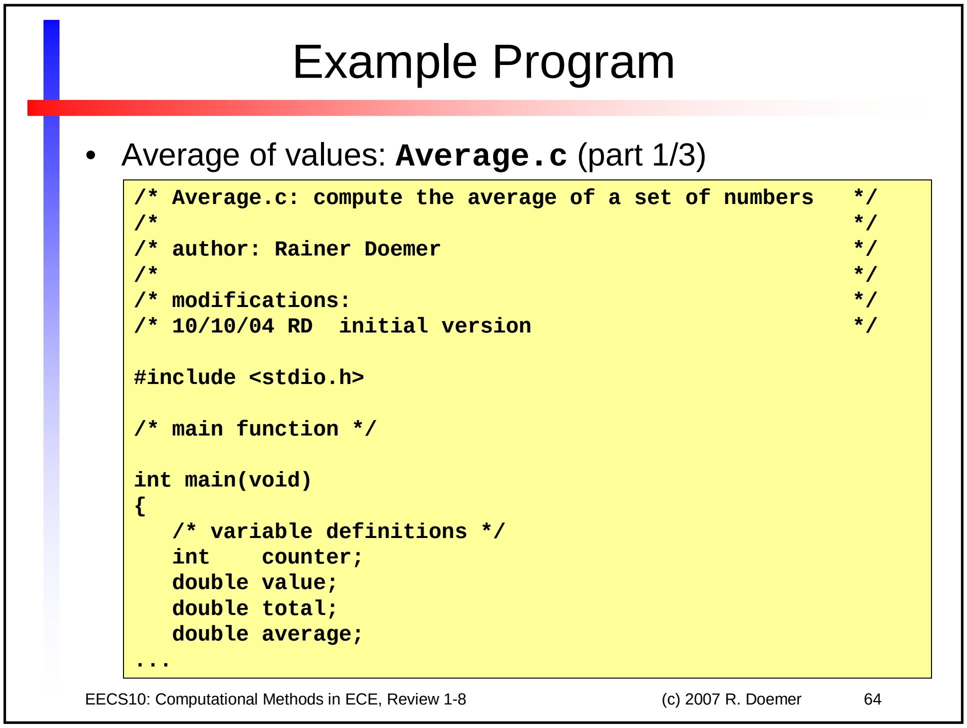


Repetition Statements

- **`while`** loop
  - Control flow statement for repetition (iteration)
    - Repeats execution depending on a specified condition
  - Example:

```
int product = 2;
while (product < 1000)
   { product *= 2; }
printf(“Product is %d”, product);
```

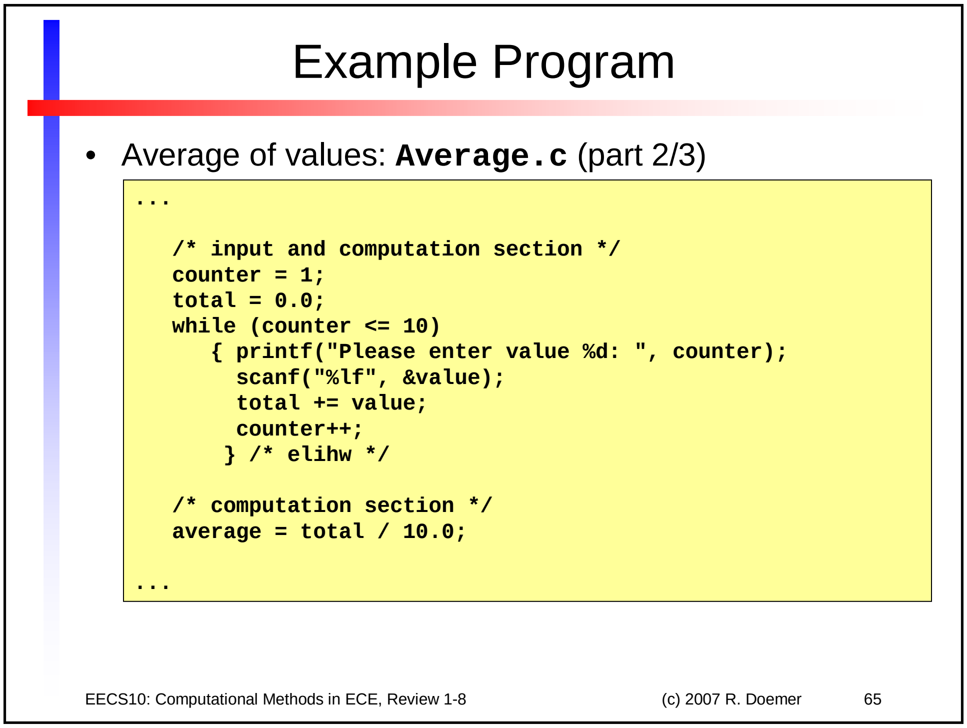
  - Syntax: **`while`** construct consists of
    - keyword **`while`**
    - condition expression evaluated to true or false
    - body statement block
  - Semantics: the body is repeatedly executed as long as the condition evaluates to true
    - the condition is evaluated at the *beginning* of each loop



Example Program

- Average of values: **`Average.c`** (part 1/3)

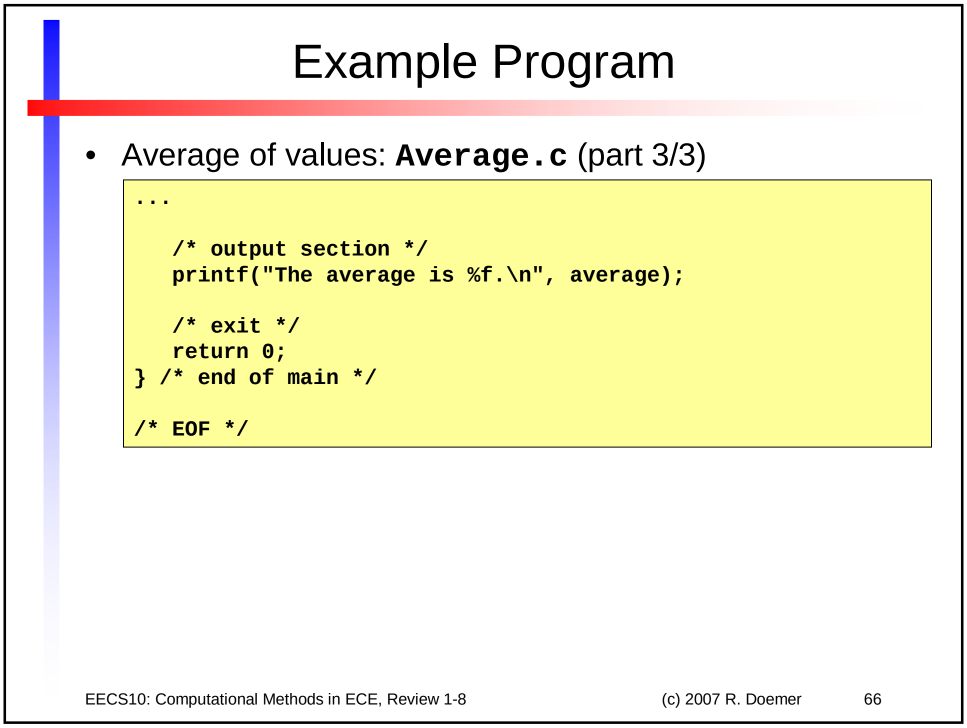
```
/* Average.c: compute the average of a set of numbers    */
/*                                                       */
/* author: Rainer Doemer                                 */
/*                                                       */
/* modifications:                                        */
/* 10/10/04 RD  initial version                          */

#include <stdio.h>

/* main function */

int main(void)
{
   /* variable definitions */
   int    counter;
   double value;
   double total;
   double average;
...
```



Example Program

- Average of values: **`Average.c`** (part 2/3)

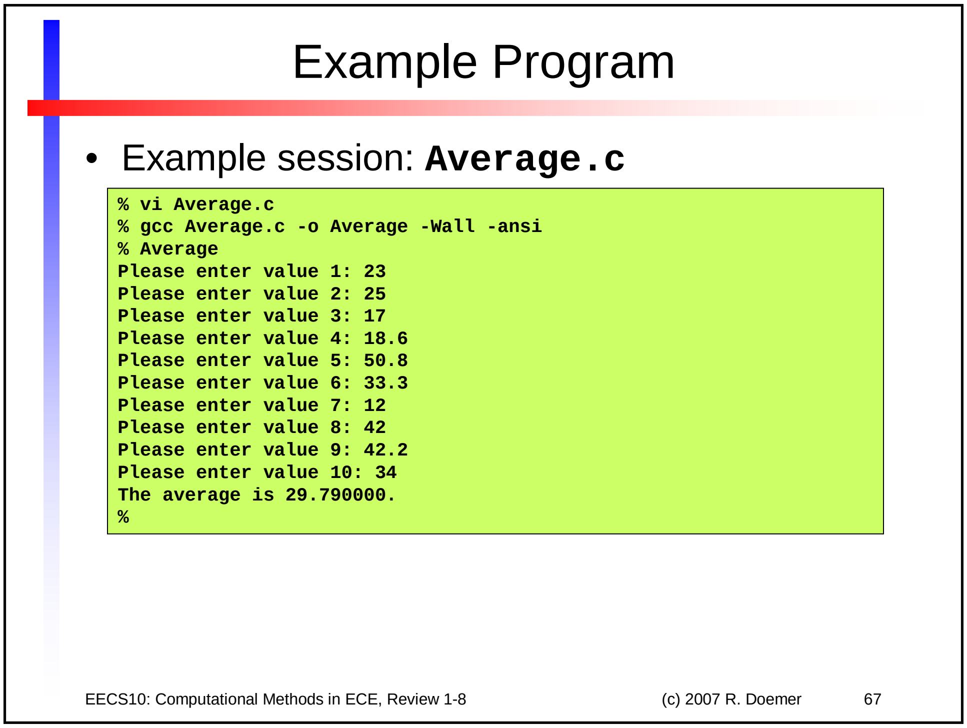
```
...

   /* input and computation section */
   counter = 1;
   total = 0.0;
   while (counter <= 10)
      { printf("Please enter value %d: ", counter);
        scanf("%lf", &value);
        total += value;
        counter++;
       } /* elihw */

   /* computation section */
   average = total / 10.0;

...
```



Example Program

- Average of values: **`Average.c`** (part 3/3)

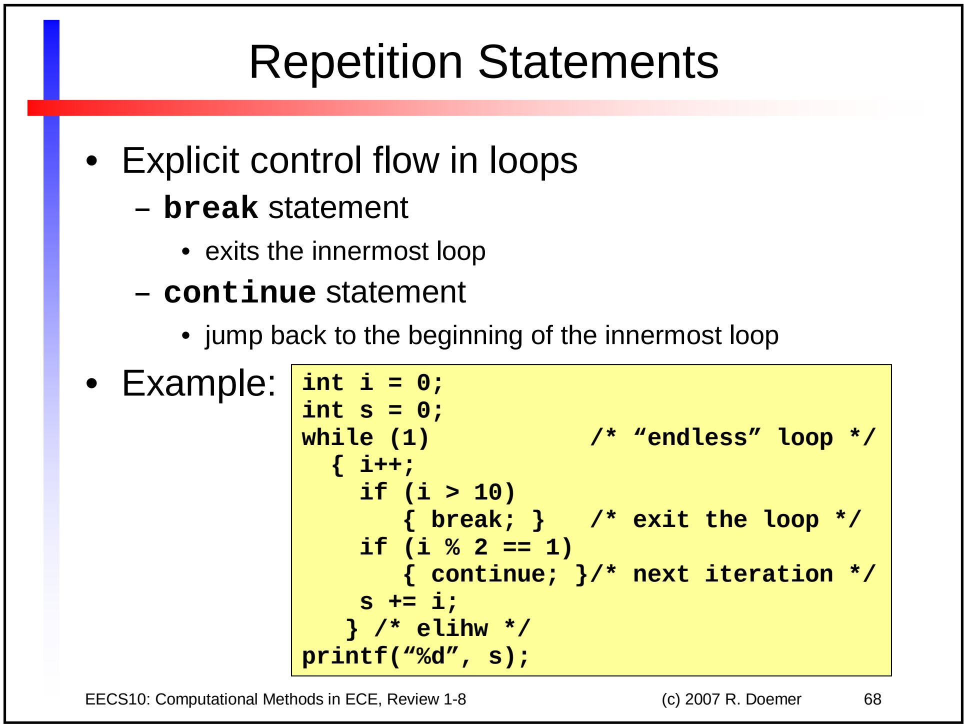
```
...

   /* output section */
   printf("The average is %f.\n", average);

   /* exit */
   return 0;
} /* end of main */

/* EOF */
```



Example Program

- Example session: **`Average.c`**

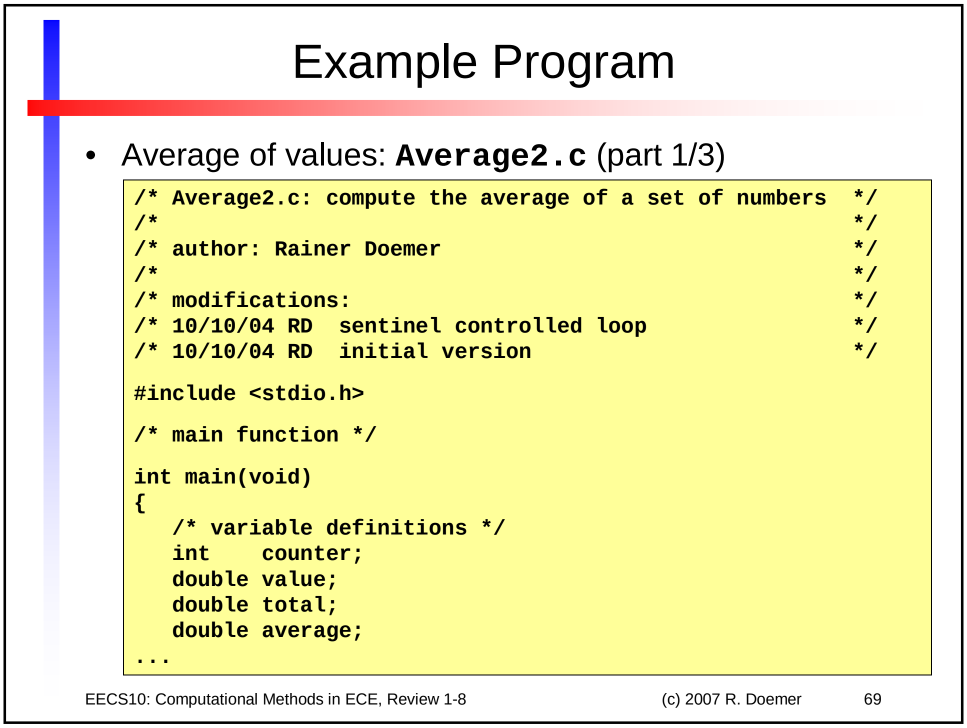
```
% vi Average.c
% gcc Average.c -o Average -Wall -ansi
% Average
Please enter value 1: 23
Please enter value 2: 25
Please enter value 3: 17
Please enter value 4: 18.6
Please enter value 5: 50.8
Please enter value 6: 33.3
Please enter value 7: 12
Please enter value 8: 42
Please enter value 9: 42.2
Please enter value 10: 34
The average is 29.790000.
%
```



Repetition Statements

- Explicit control flow in loops
  - **`break`** statement
    - exits the innermost loop
  - **`continue`** statement
    - jump back to the beginning of the innermost loop
- Example:

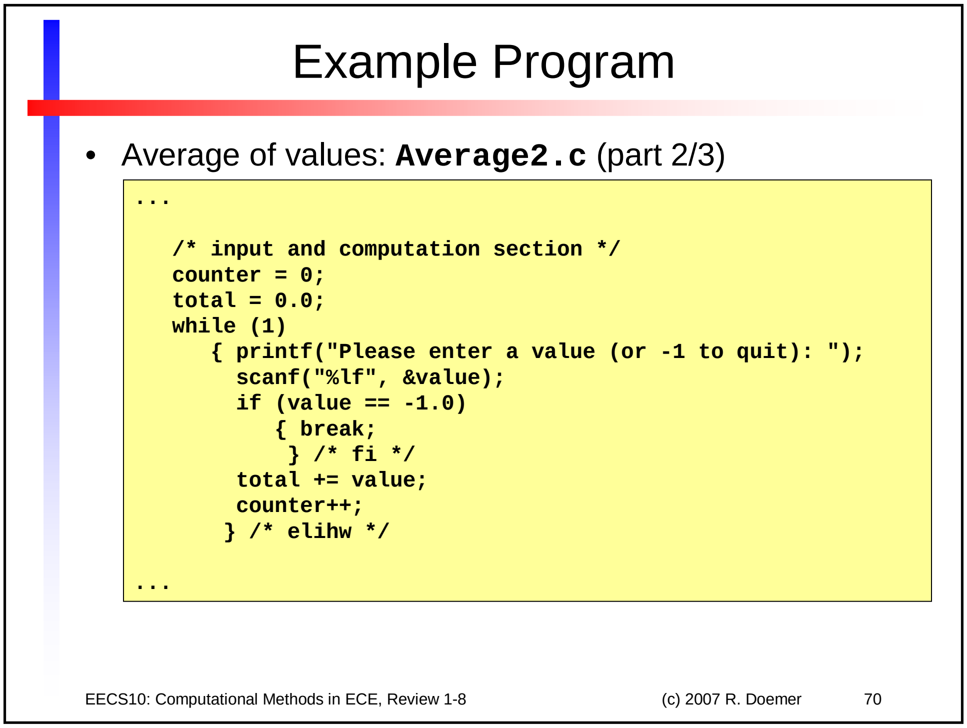
```
int i = 0;
int s = 0;
while (1)           /* “endless” loop */
  { i++;
    if (i > 10)
       { break; }   /* exit the loop */
    if (i % 2 == 1)
       { continue; }/* next iteration */
    s += i;
   } /* elihw */
printf(“%d”, s);
```



Example Program

- Average of values: **`Average2.c`** (part 1/3)

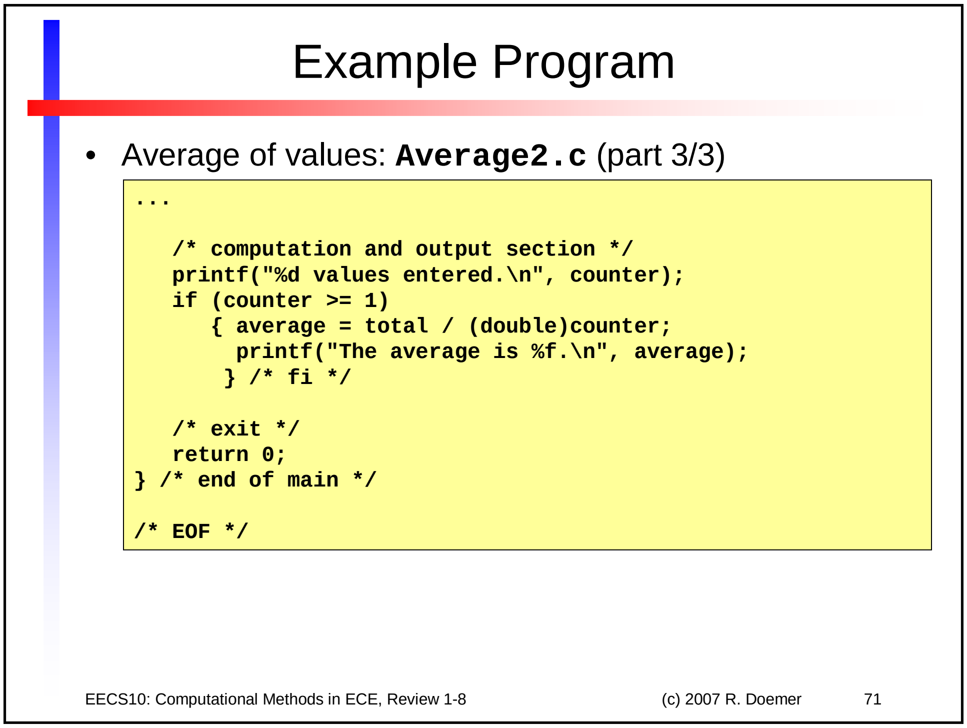
```
/* Average2.c: compute the average of a set of numbers  */
/*                                                      */
/* author: Rainer Doemer                                */
/*                                                      */
/* modifications:                                       */
/* 10/10/04 RD  sentinel controlled loop                */
/* 10/10/04 RD  initial version                         */

#include <stdio.h>

/* main function */

int main(void)
{
   /* variable definitions */
   int    counter;
   double value;
   double total;
   double average;
...
```



Example Program

- Average of values: **`Average2.c`** (part 2/3)

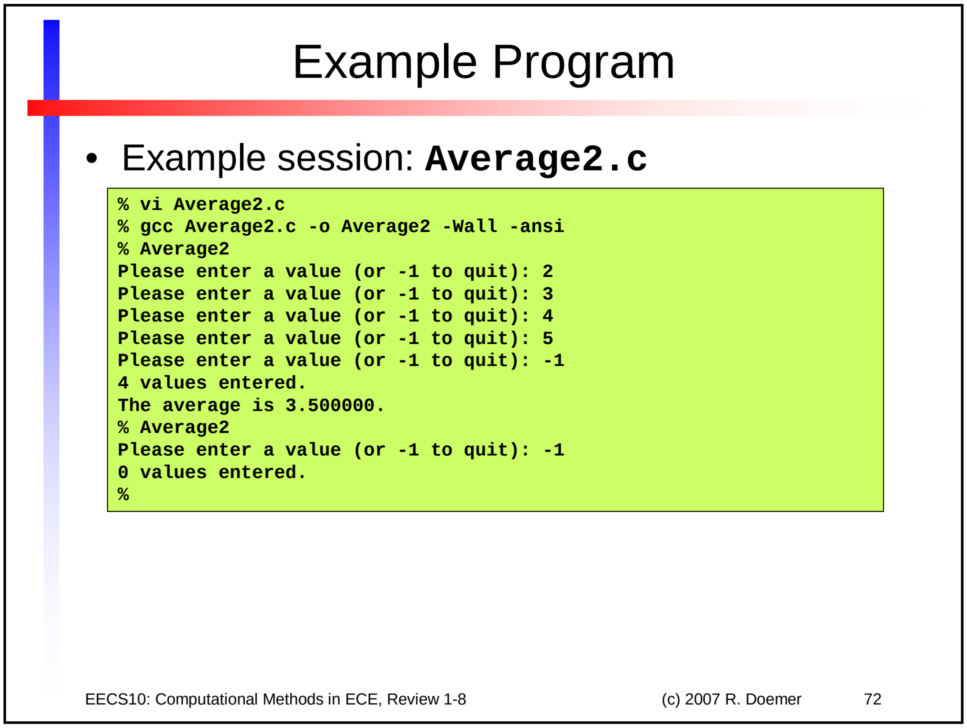
```
...

   /* input and computation section */
   counter = 0;
   total = 0.0;
   while (1)
      { printf("Please enter a value (or -1 to quit): ");
        scanf("%lf", &value);
        if (value == -1.0)
           { break;
            } /* fi */
        total += value;
        counter++;
       } /* elihw */

...
```



Example Program

- Average of values: **`Average2.c`** (part 3/3)

```
...

   /* computation and output section */
   printf("%d values entered.\n", counter);
   if (counter >= 1)
      { average = total / (double)counter;
        printf("The average is %f.\n", average);
       } /* fi */

   /* exit */
   return 0;
} /* end of main */

/* EOF */
```



Example Program

- Example session: **`Average2.c`**

```
% vi Average2.c
% gcc Average2.c -o Average2 -Wall -ansi
% Average2
Please enter a value (or -1 to quit): 2
Please enter a value (or -1 to quit): 3
Please enter a value (or -1 to quit): 4
Please enter a value (or -1 to quit): 5
Please enter a value (or -1 to quit): -1
4 values entered.
The average is 3.500000.
% Average2
Please enter a value (or -1 to quit): -1
0 values entered.
%
```