Problem Solving With C - UE24CS151B

C Programming Environment

Prof. Sindhu R Pai
PSWC Theory Anchor, Feb-May, 2025
Department of Computer Science and Engineering

PROBLEM SOLVING WITH C

C Programming Environment

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1. Installation of gcc on different Operating systems
2. Program Development Life Cycle [PDLC]
3. First Program in C
4. Structure of C Program
5. Steps involved in execution of C Program
6. C Compiler standards
7. Errors during execution

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Installation of gcc on different Operating systems

- Windows OS – Installation of gcc using Mingw.
  - https://www.youtube.com/watch?v=sXW2VLrQ3Bs

- Linux OS – gcc available by default

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Program Development Life Cycle [PDLC]

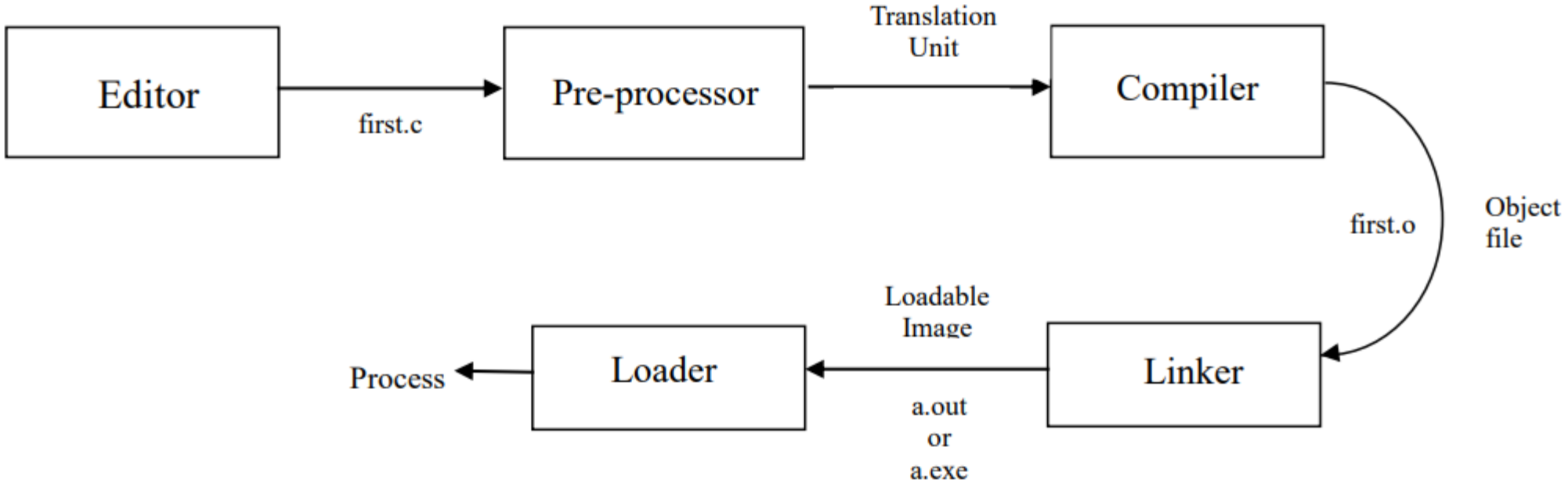

Fig 1: Phases involved in PDLC

First Program in C

```
#include<stdio.h>
int main()
{
        printf("Hello PES\n");
        return 0;
}

//Importance of int main and return values
```

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Program Structure

- Case sensitive
- Indentation is not a language requirement
- The main() is the starting point of execution
- Comments in C
  - Using // for single line comment
  - Using /* and */ for multiline comment

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Steps involved in execution of code

Way 1:

Step1: gcc <filename> // image a.out is the output
Step2: ./a.out OR a.exe

Way 2: Creating the object files separately

Compile: gcc -c <filename> // filename.o is the output
Link: gcc filename.o OR gcc <list of object files> -l <library>
Execute: ./a.out OR a.exe

Way 3: Renaming the object files

Step1: gcc <filename> -o <imagename>
Step2: <imagename>

C Compiler standards

Standardized by ANSI and ISO: **C89, C99 and C11**

Using c99:
gcc -std=c99 program.c

Using c11:
gcc -std=c11 program.c

Use **__STDC_VERSION__** we can get the standard C version

Errors during Execution

- Compile time Error
- Link time Error
- Run time Error
- Logical Error

// One Example on each of these

THANK YOU

Department of Computer Science and Engineering

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Ack: Teaching Assistant - U Shivakumar

UE24CS151B: Problem Solving with C - Introduction for B.Tech Second Semester A & N Section - EC Campus Lecture Slides - Slot #4, #5, #6

Nitin V Pujari
Faculty, Computer Science
Dean - IQAC, PES University

UE24CS151B: Problem Solving with C - Syllabus

Unit I: Problem Solving Fundamentals - 14 Hours - 18 Slots

Introduction to Programming, Salient Features of 'C', Program Structure, Variables, Data Types & range of values ,Qualifiers, Operators and Expressions, Control Structures, Input/Output Functions, Language Specifications -Behaviors, Single character input and output, Coding standards and guidelines

Unit II: Counting, Sorting and Searching – 14 Hours - 18 Slots

Arrays–1D and 2D, Pointers, Pointer to an array, Array of pointers, Functions, Call back, Storage classes, Recursion, Searching, Sorting

Unit III: Text Processing and User-Defined Types - 14 Hours - 18 Slots

Strings, String Manipulation Functions & Error handling, Command line arguments, Dynamic Memory Management functions & Error handling, Structures, #pragma, Array of Structures, Pointer to structures, Passing Structure and Array of structure to a function, Bit fields, Unions, Enums, Lists, Stack, Queue, Priority Queue.

Unit IV: File Handling and Portable Programming – 14 Hours – 18 Slots

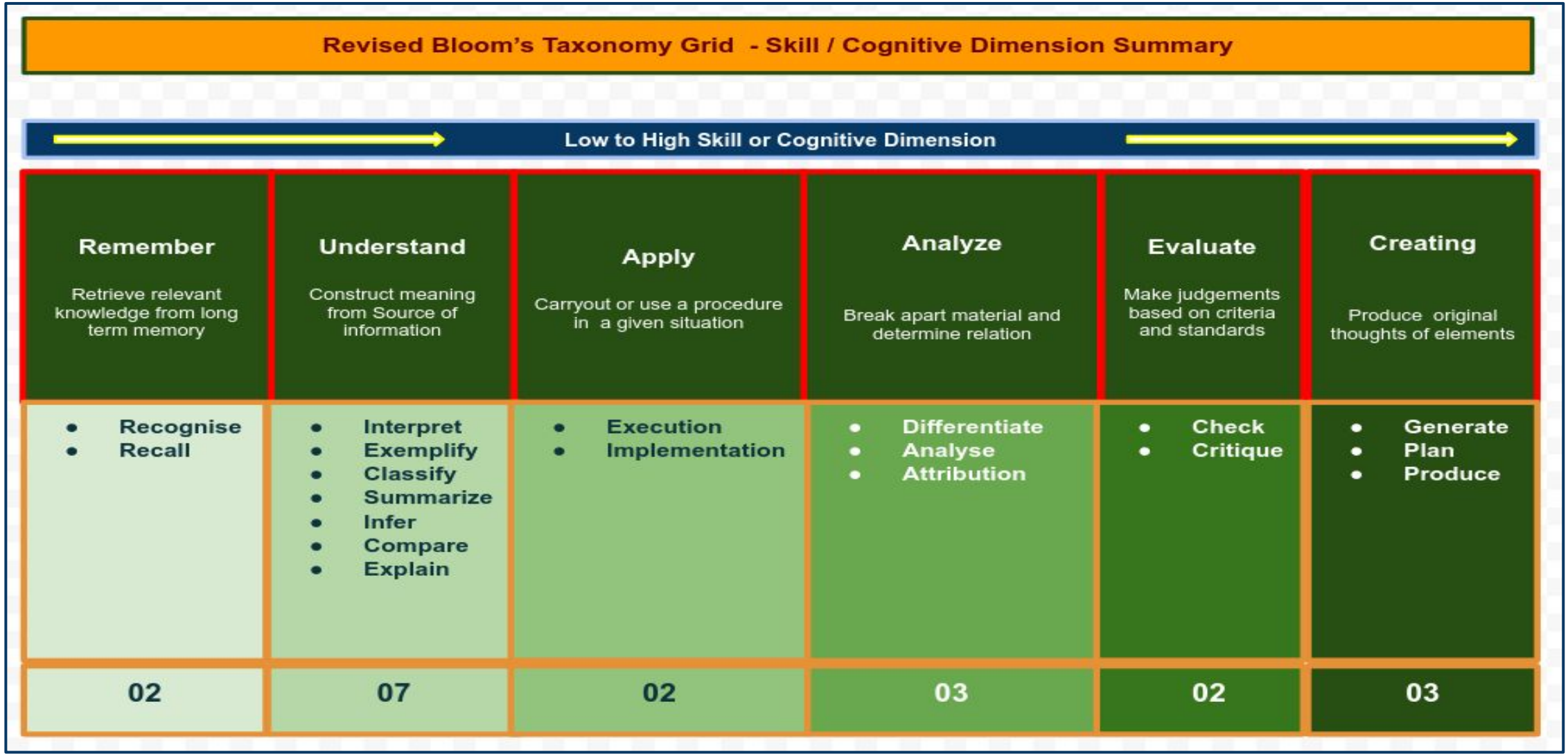
File IO using redirection, File Handling functions of C, Searching, Sorting, Header files, Comparison of relevant User defined and Built-in functions, Variable Length Arguments, Environment variables, Preprocessor Directives, Conditional Compilation.

UE24CS151B: Problem Solving with C - Course Objectives

The objective(s) of this course is to make students

- **CObj1: Acquire knowledge on how to solve relevant and logical problems using computing machine**
- **CObj2: Map algorithmic solutions to relevant features of C programming language constructs**
- **CObj3: Gain knowledge about C constructs and its associated ecosystem**
- **CObj4: Appreciate and gain knowledge about the issues with C Standards and its respective behaviours**

Bloom's Taxonomy



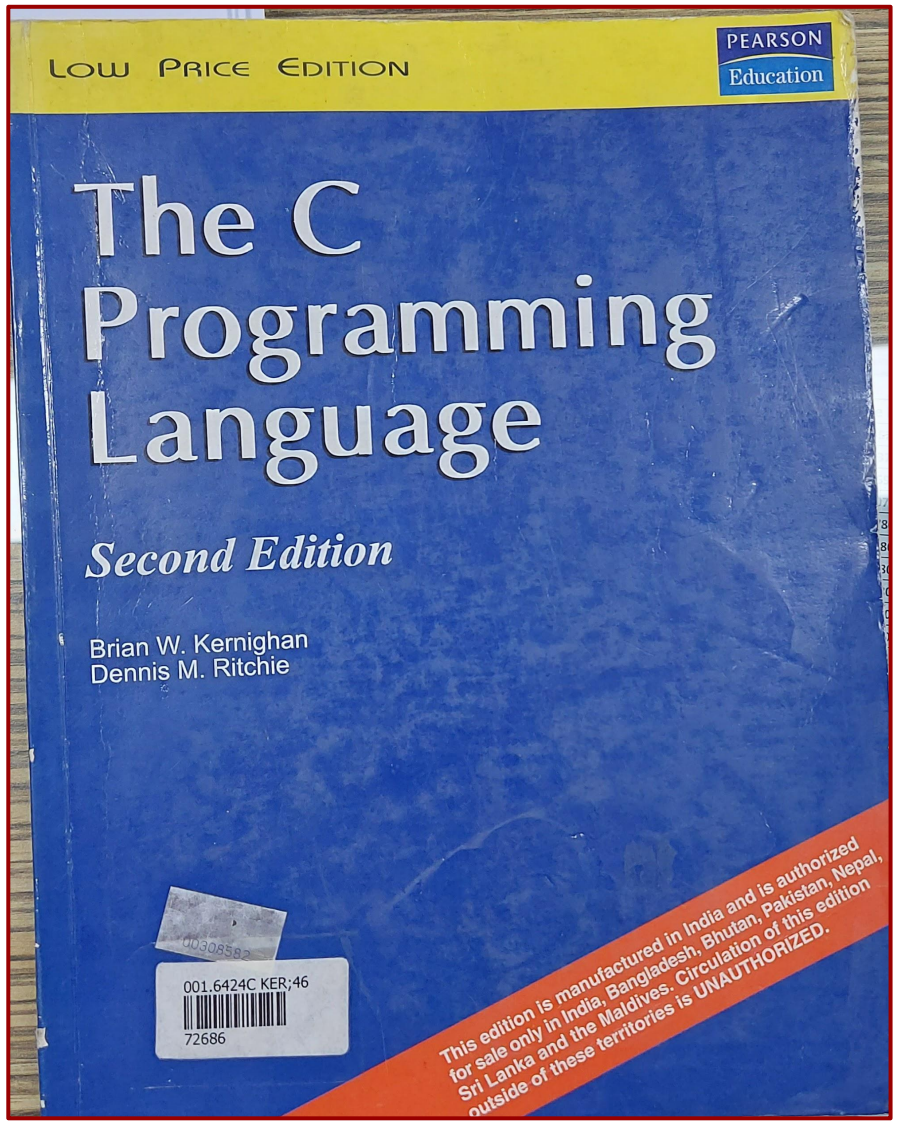
Remember	Understand	Apply	Analyze	Evaluate	Creating
Retrieve relevant knowledge from long term memory	Construct meaning from Source of information	Carryout or use a procedure in a given situation	Break apart material and determine relation	Make judgements based on criteria and standards	Produce original thoughts of elements
• Recognise • Recall	• Interpret • Exemplify • Classify • Summarize • Infer • Compare • Explain	• Execution • Implementation	• Differentiate • Analyse • Attribution	• Check • Critique	• Generate • Plan • Produce
02	07	02	03	02	03

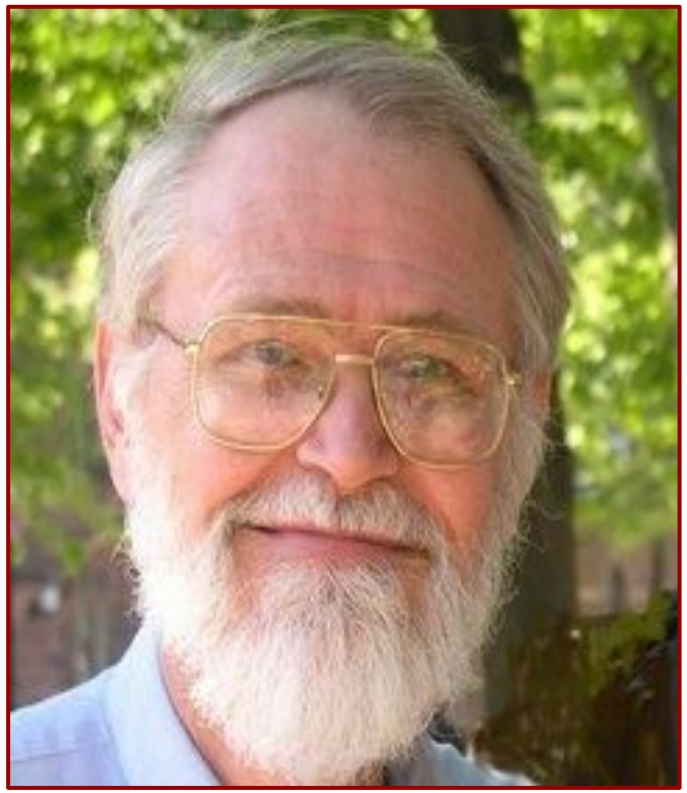
UE24CS151B: Problem Solving with C - Course Outcomes

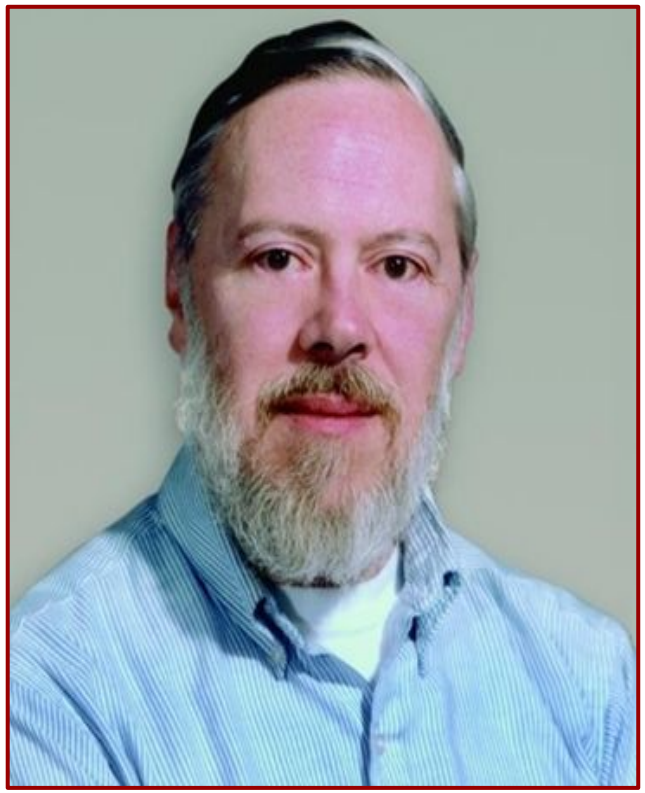
At the end of the course, the student will be able to

- CO1: Understand and apply algorithmic solutions to counting problems using appropriate C constructs
- CO2: Understand, analyse and apply Sorting and Searching techniques
- CO3: Understand, analyse and apply text processing and string manipulation methods using Arrays, Pointers and functions
- CO4: Understand user defined type creation and implement the same using C structures, unions and other ways by reading and storing the data in secondary systems which are portable.

UE24CS151B: Problem Solving with C Text Book







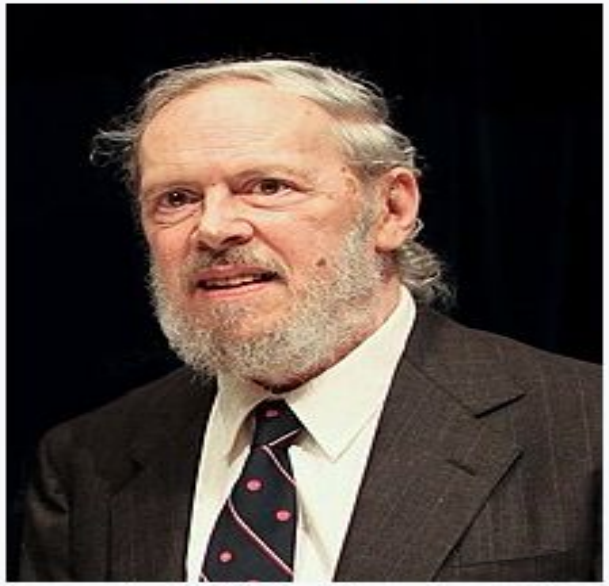
UE24CS151B: About Text Book Authors

Brian Kernighan

Brian Kernighan at Bell Labs in 2012

Born	Brian Wilson Kernighan 1942 (age 79–80)[1] Toronto, Ontario, Canada
Nationality	Canadian
Citizenship	Canada
Alma mater	University of Toronto (BASc) Princeton University (PhD)

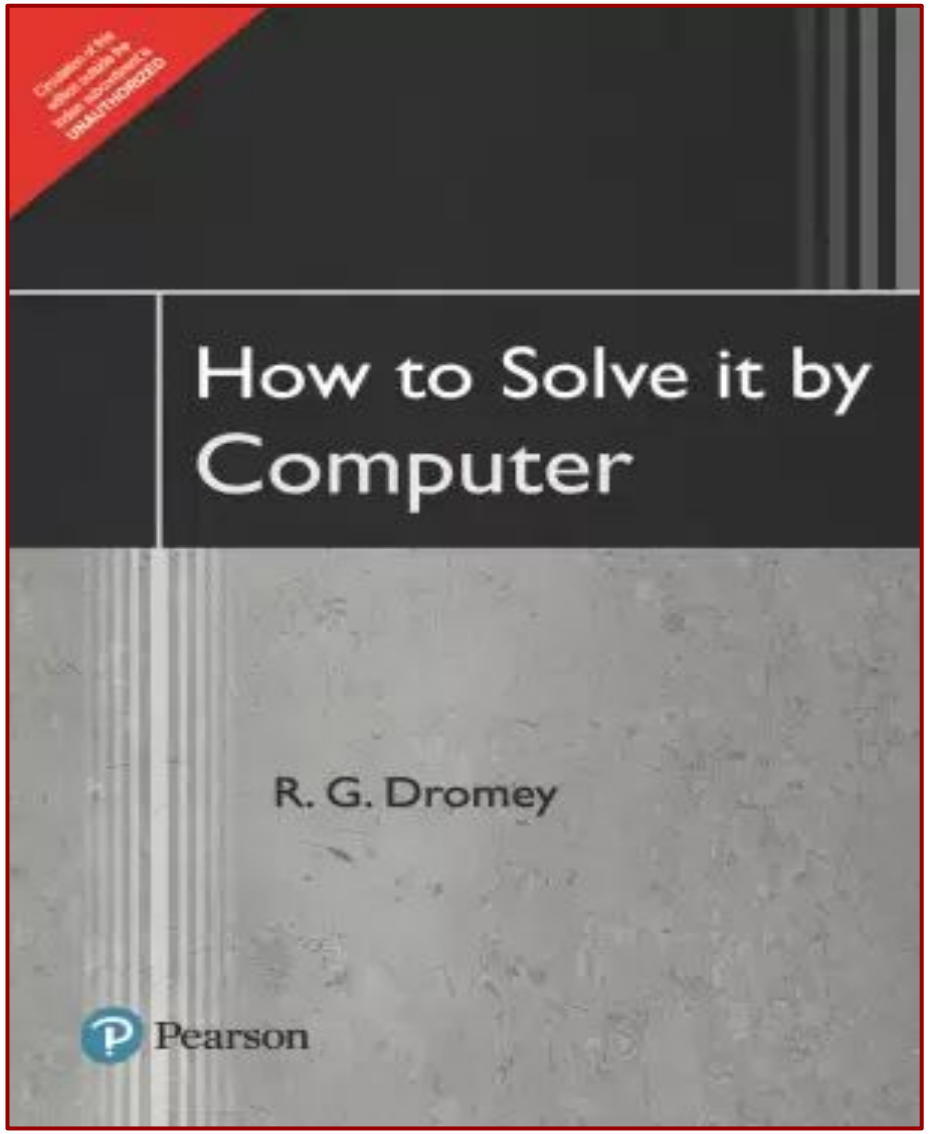
Dennis Ritchie

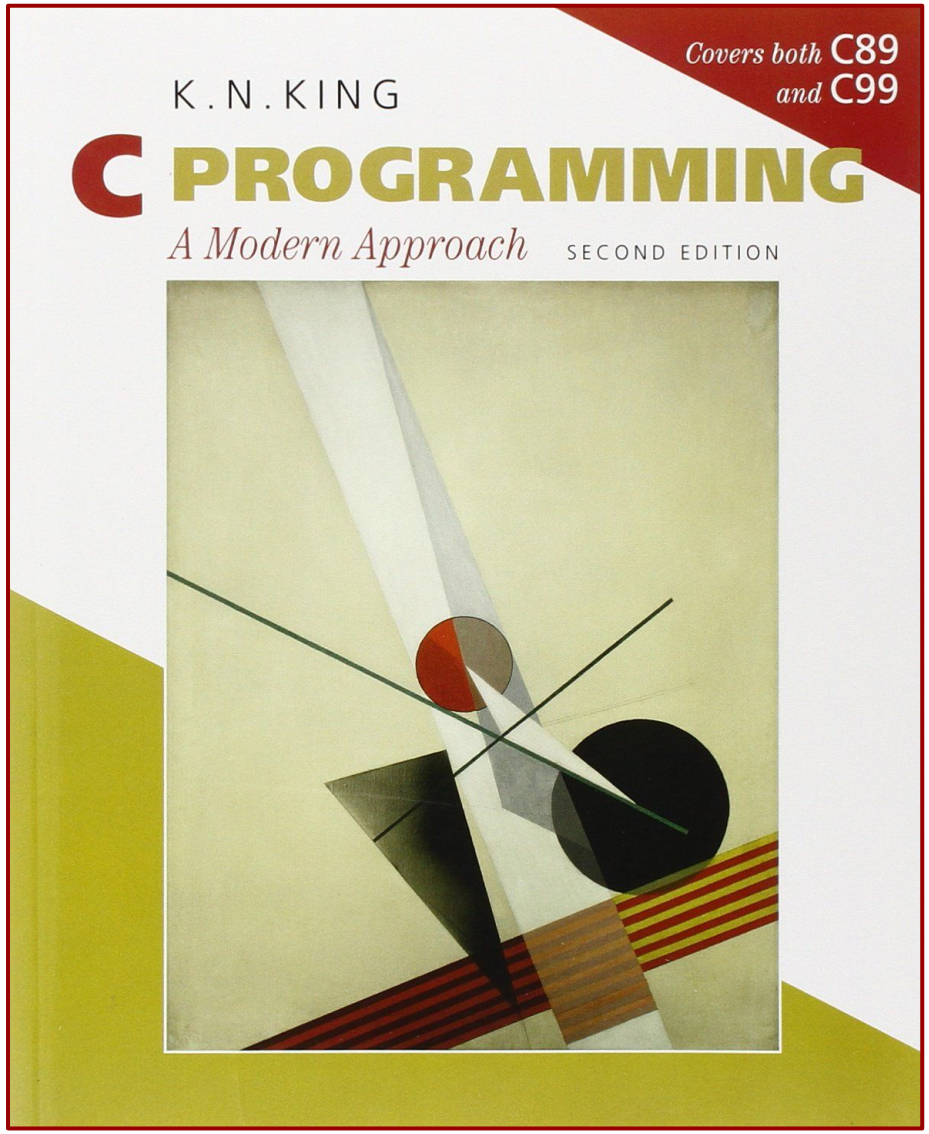


Dennis Ritchie at the Japan Prize Foundation in May 2011

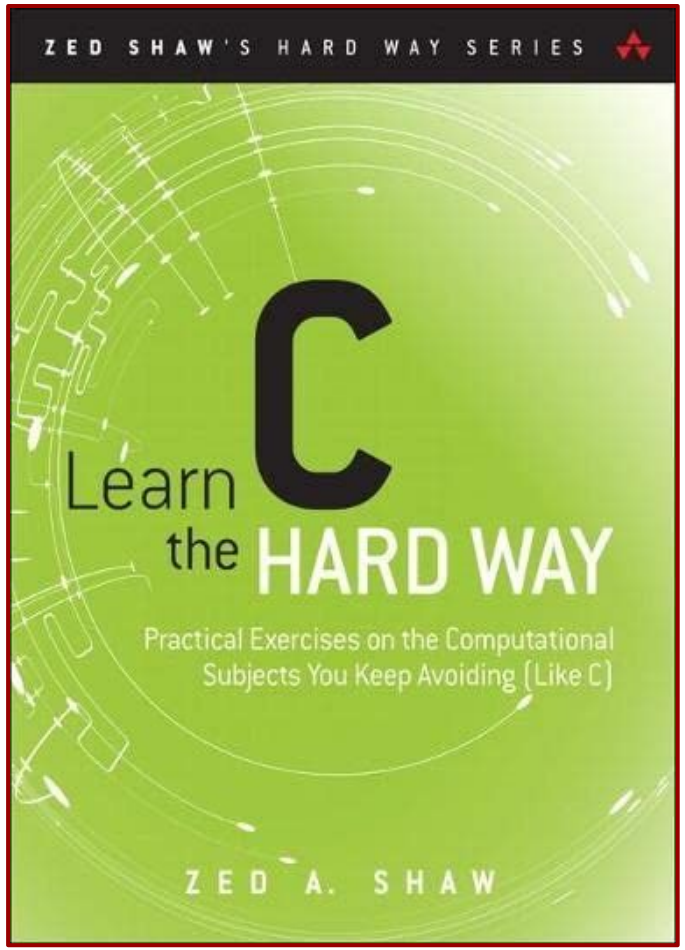
Born	September 9, 1941[1][2][3][4] Bronxville, New York, U.S.
Died	c. October 12, 2011 (aged 70) Berkeley Heights, New Jersey, U.S.
Nationality	American
Alma mater	Harvard University (Ph.D., 1968)

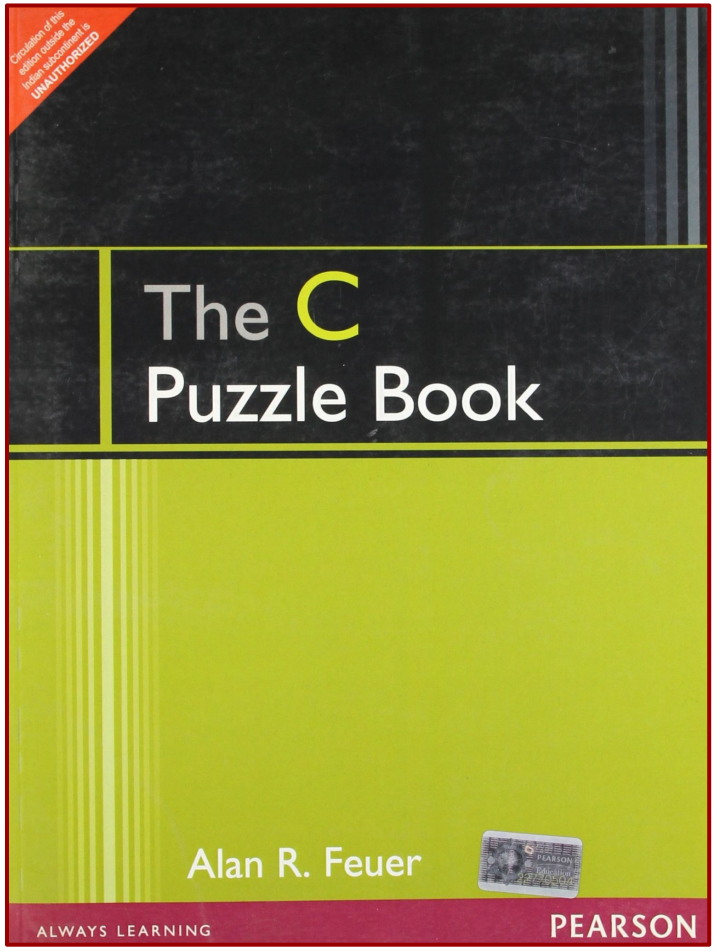
UE24CS151B: Problem Solving with C Reference Books

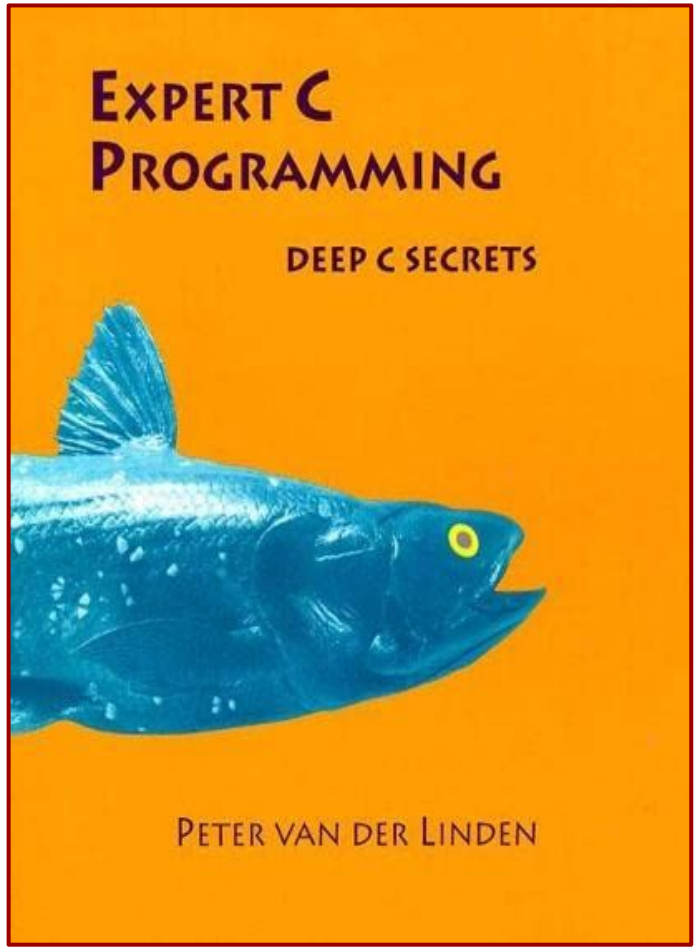




UE24CS151B: Problem Solving with C Reference Books







UE24CS151B : PSWC: Unit 1 - gcc Insights

- The original author of the GNU C Compiler (**gcc**) is **Richard Stallman**, the founder of the **GNU** Project
- **GNU** stands for **GNU's not Unix**
- The GNU Project was started in **1984** to create a complete Unix-like operating system as **free software**, in order to promote freedom and cooperation among computer users and programmers
- The **first** release of **gcc** was made in **1987,** as the first portable ANSI C optimizing compiler released as free software
- A major revision of the compiler came with the **2.0** series in **1992**, which added the ability to compile **C++**
- The acronym **gcc** is now used to refer to the "**GNU Compiler Collection**"
- **gcc** has been extended to support many additional languages, including Fortran, ADA, Java and Objective-C
- Its development is guided by the **gcc** Steering Committee, a group composed of representatives from **gcc** user communities in industry, research and academia

UE24CS151B : PSWC: Unit 1 - gcc Features

- **gcc** is a portable compiler, it runs on most platforms available today, and can produce **output** for many types of **processors**
- **gcc** also supports **microcontrollers**, **DSPs** and **64-bit** CPUs
- **gcc** is not only a native compiler, it can also cross-compile any program, producing executable files for a different system from the one used by **gcc** itself.
- **gcc** allows software to be compiled for embedded systems which are not capable of running a compile
- **gcc** written in C with a strong focus on portability, and can compile itself, so it can be adapted to new systems easily
- **gcc** has multiple language frontends, for parsing different languages
- **gcc** can compile or cross-compile programs in each language, for any architecture
- **gcc,** for example,can compile an ADA program for a **microcontroller**, or a C program for a **supercomputer**

UE24CS151B : PSWC: Unit 1 - gcc Features

- **gcc** has a modular design, allowing support for new languages and architectures to be added.

- **gcc** is free software, distributed under the GNU General Public License (GNU GPL), which means we have the freedom to use and to modify **gcc**, as with all GNU software.

- **gcc** users have the freedom to share any enhancements and also make use of enhancements to **gcc** developed by others.

- If we need support for a new type of **CPU**, a new language, or a new feature we can add it ourselves, or hire someone to enhance **gcc** for us, in addition we can hire someone to fix a bug if it is important for our work

UE24CS151B : PSWC: Unit 1 - gcc for c programming

- c is one those languages that allow **direct** access to the computer's **memory**.
- Historically, **c** has been used for writing low-level systems software, and applications where **high performance** or control over resource usage are **critical**
- Great care is required to ensure that memory is accessed correctly, to avoid corrupting other data-structures whenever one uses **c** language for programming
- In addition to C , the GNU Project also provides other high-level languages, such as C++, GNU Common Lisp (gcl), GNU Smalltalk (gst), the GNU Scheme extension language (guile) and the GNU Compiler for Java (gcj).
- These languages with exception to **c** and **c++**, do not allow the user to access memory directly, **eliminating** the possibility of **memory access errors**.
- They are a safer alternative to c and c++ for many applications

UE24CS151B : PSWC: Unit 1 - Compiling a c program using gcc

- **c** programs can be compiled from a single source file or from multiple source files, and may use system libraries and header files

- Compilation refers to the process of converting a program from the textual source code, in a programming language such as **c** into machine code, the sequence of 1's and 0's used to control the central processing unit (CPU) of the computer.

- **Machine code** is then **stored** in a file known as an **executable** file, sometimes referred to as a **binary** file

UE24CS151B : PSWC: Unit 1 - Compiling a c program using gcc

- `gcc -Wall PESU.c -o PESU`
- This compiles the source code in **PESU.c** to machine code and stores it in an executable file **PESU**'.
- The output file for the machine code is specified using the **'-o'** option.
- **-o** option is **usually** given as the **last** argument on the **command line**, If it is omitted, the output is written to a default file called **'a.out'**.
- If a file with the same name as the executable file already exists in the current directory it will be overwritten
- The option **'-Wall' turns on** all the most commonly-used **compiler warnings**, it is **recommended** that we always **use** this **option**!
- **gcc** will not produce any warnings **unless** they are **enabled**.
- Compiler **warnings** are an essential aid in **detecting** problems when programming in **c**
- Source code which does not produce any warnings by **gcc**, is said to be **compile cleanly**.

UE24CS151B : PSWC: Unit 1 - Finding errors in a simple program using gcc

- Compiler **warnings** are an essential aid when programming in c
- **Error** is not obvious at first sight, but can be detected by the compiler if the warning option '-Wall' has been enabled for **safety**
- The compiler distinguishes between **error** messages, which prevent successful compilation, and **warning** messages which indicate possible problems but **do not stop** the program from compiling
- It is very **dangerous** to develop a program **without checking** for compiler **warnings**.
- If there are any functions which are not used correctly they can cause the program to crash or produce incorrect results.
- Turning on the compiler warning option **'-Wall'** for safety will catch many of the commonest errors which occur in c programming

UE24CS151B : PSWC: Unit 1 - Creating object files from source files using gcc

- The command-line option '**-c**' is used to compile a source file to an **object** file.
- '-c' produces an object file '**<filename>.o**' containing the machine code for the main function.
- '**<filename>.o**' contains a reference to the **external** function <filename>, but the corresponding memory address is left undefined in the object file at this stage, which will be filled in later by linking
- There is **no need** to use the option '-o' to specify the name of the output file in this case.
- When compiling with '-c' the compiler **automatically** creates an object file whose name is the same as the source file, but with **'.o'** instead of the original extension

- The list of directories for **header files** is often referred to as the include path, and the list of directories for libraries as the library search path or link path
- For example, a header file found in '/usr/local/include' takes precedence over a file with the same name in '/usr/include'.
- Similarly, a library found in '/usr/local/lib' takes precedence over a library with the same name in '/usr/lib'
- When additional libraries are installed in other directories it is necessary to extend the search paths, in order for the libraries to be found.
- The compiler options '-I' and '-L' add new directories to the beginning of the include path and library search path respectively

UE24CS151B : PSWC: Unit 1 - c Language Standards using gcc

- By default, **gcc** compiles programs using the **GNU** dialect of the C language, referred to as **GNU C**
- This dialect incorporates the official ANSI/ISO standard for the C language with several useful GNU extensions, such as nested functions and variable-size arrays.
- Most ANSI/ISO programs will compile under GNU C without changes
  - `gcc -Wall -ansi <filename.c>`
  - `gcc -Wall <filename.c>`
- The command-line option '-pedantic' in combination with '-ansi' will cause gcc to reject all GNU C extensions, not just those that are incompatible with the ANSI/ISO standard
  - `gcc -Wall -ansi -pedantic <filename.c>`
- The following options are a good choice for finding problems in C programs
  - `gcc -ansi -pedantic -Wall -W -Wconversion -Wshadow -Wcast-qual -Wwrite-strings`

Note: **While this list is not exhaustive, regular use of these options will catch many common errors.**

- **Error**
  - a mistake
  - the state or condition of being wrong in conduct or judgement
  - a measure of the estimated difference between the observed or calculated value of a quantity and its true value
- **Preprocessor Error**
  - #error is a preprocessor directive in c which is used to raise an error during compilation and terminate the process

- **Compile time Error**
  - When the programmer does not follow the syntax of any programming language, then the compiler will throw the **Syntax Error**, such errors are also called **Compile Time Error**
  - **Syntax Errors** are easy to figure out because the compiler highlights the line of code that caused the error.

- **Linker Error**

  - **Linker** is a program that takes the object files generated by the compiler and combines them into a single executable file.

  - **Linker Errors** are the errors encountered when the executable file of the code can not be generated even though the code gets compiled successfully.

  - This **Error** is generated when a different object file is unable to link with the main object file.

  - We can run into a linked error if we have imported an incorrect header file in the code

- **Runtime Error**
  - Errors that occur during the execution (or running) of a program are called **Runtime Errors.** These errors occur after the program has been compiled and linked successfully.
  - When a program is running, and it is not able to perform any particular operation, it means that we have encountered a runtime error.

UE24CS151B : PSWC: Unit 1 - Errors

- **Logical Error**
  - Sometimes, we do not get the output we expected after the compilation and execution of a program.
  - Even though the code seems error free, the output generated is different from the expected one.
  - These types of errors are called **Logical Errors**.
- **Semantic Errors**
  - Errors that occur because the compiler is unable to understand the written code are called Semantic Errors.
  - A semantic error will be generated if the code makes no sense to the compiler, even though it is syntactically correct.
  - It is like using the wrong word in the wrong place in the English language

UE24CS151B : PSWC: Unit 1 - Simple Input / Output Function

- Input and output functions are available in the **c language** to perform the most common tasks.
- In every **c program**, three basic functions take place namely **accepting of data as input**, **the processing of data**, and **the generation of output**
- When a **programmer** says **input**, it would mean that they are **feeding** some **data** in the program.
- Programmer can give this **input** from the **command line** or **in the form of any file**.
- The **c programming language** comes with a set of various **built-in functions** for **reading** the **input** and then **feeding** it to the available program as per our requirements.
- When a **programmer** says **output**, they mean **displaying** some **data** and **information** on the **printer**, the **screen**, or any other **file**.
- The **c programming language** comes with various **built-in functions** for **generating** the **output** of the **data** on any **screen** or **printer**, and also redirecting the output in the form of binary files or text file.

UE24CS151B : PSWC: Unit 1 - Unformatted I/O

- The **unformatted functions** are **not capable** of **controlling** the **format** that is involved in **writing** and **reading** the available **data**.
- Hence **these functions** constitute the most **basic** forms of **input** and **output**.
- The supply of input or the display of output **isn't allowed** in the **user format**, hence we call these functions as **unformatted functions** for **input** and **output**.
- The unformatted input-output functions further have two categories:
    - The **character** functions
        - We use the character input functions for reading only a single character from the input device by default the keyboard
            - **getchar(), getche(),** and the **getch()** refer to the **input functions** of **unformatted type**
        - we use the character output functions for writing just a single character on the output source by default the screen
            - the **putchar()** and **putch()** refer to the output functions of unformatted type

UE24CS151B : PSWC: Unit 1 - Unformatted I/O

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- Hence **these functions** constitute the most **basic** forms of **input** and **output**.
- The supply of input or the display of output **isn't allowed** in the **user format**, hence we call these functions as **unformatted functions** for **input** and **output**.
- The unformatted input-output functions further have two categories:
    - The **string** functions
        - In any programming language including c, the **character array** or **string** refers to the **collection** of various **characters**
        - Various types of **input and output** functions are present in **c programming** that can easily read and write these strings.
            - The **puts()** and **gets()** are the most commonly used ones for **unformatted** forms
            - **gets()** refers to the **input** function used for **reading** the **string** characters
            - **puts()** refers to the **output** function used for **writing** the **string** characters

UE24CS151B : PSWC: Unit 1 - Formatted Output in C - printf

- **printf()**
  - This function is used to display one or multiple values in the output to the user at the console.
    - int printf(const char *format, ...)
    - Predefined function in stdio.h
    - Sends formatted output to stdout by default
    - Output is controlled by the first argument
    - Has the capability to evaluate an expression
    - On success, it returns the number of characters successfully written on the output.
    - On failure, a negative number is returned.
    - Arguments to printf can be expressions
  - While calling any of the formatted console input/output functions, we must use a specific format specifiers in them, which allow us to read or display any value of a specific primitive data type.
  - % [flags] [field_width] [.precision] conversion_character where components in brackets [] are optional.
  - The minimum requirement is % and a conversion character (e.g. %d)
    - %d, %x, %o, %f, %c, %p, %lf, %s

UE24CS151B : PSWC: Unit 1 - keywords in c language

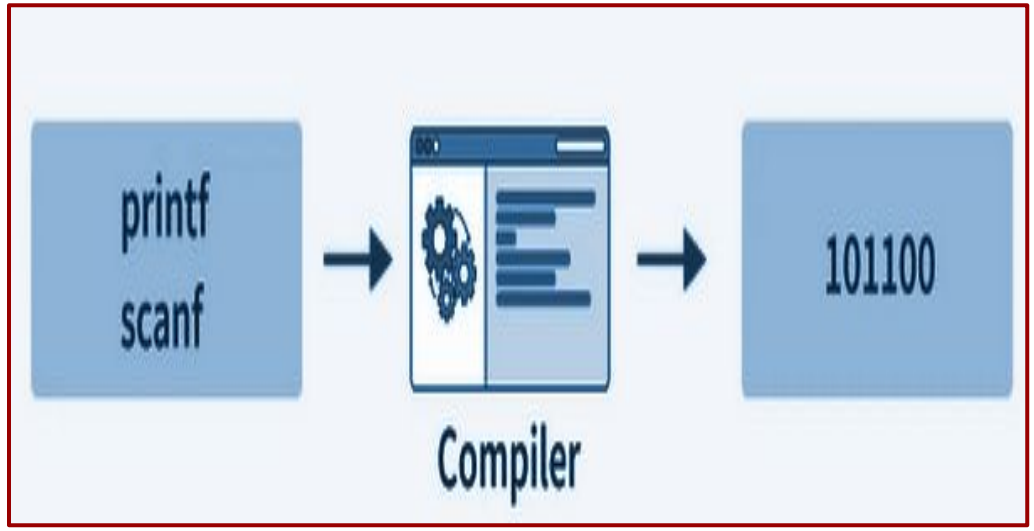
Keywords in C Programming			
auto	break	case	char
const	continue	default	do
double	else	enum	extern
float	for	goto	if
int	long	register	return
short	signed	sizeof	static
struct	switch	typedef	union
unsigned	void	volatile	while

There are **32** keywords in c Language

There are **33** keywords in python

- **Compile time** is the period when the programming code is converted to the machine code.

- **Runtime** is the period of time when a program is running and generally occurs after compile time



UE24CS151B : PSWC: Unit 1 - Compile time and Runtime in c

Compile-time error	Run-time error
These errors are detected during the compile-time	These errors are detected at the run-time
Compile-time errors do not let the program be compiled	Programs with run-time errors are compiled successfully but an error is encountered when the program is executed
Errors are detected during the compilation of the program	Errors are detected only after the execution of the program
Compile-time errors can occur because of wrong syntax or wrong semantics	Run-time errors occur because of absurd operations

UE24CS151B : PSWC: Unit 1 - sizeof operator in c Language

- The **sizeof** operator is the most common operator in C.
- It is a **compile-time unary operator** and is used to compute the size of its operand.
- It returns the size of a variable.
- It can be applied to any data type, float type, pointer type variables
- When **sizeof()** is used with the data types, it simply returns the amount of memory allocated to that data type.
- The output can be different on **different machines** like a **32-bit system** can show different output while a **64-bit system** can show different of same data types

UE24CS151B : PSWC: Unit 1 - Literals and Constants in c Language

- **Literals** are the constant values assigned to the **constant** variables.
- There are **four** types of literals that exist in c programming:
  - **Integer literal**
    - It is a numeric literal that represents only integer type values.
    - It represents the value neither in fractional nor exponential part.
    - It can be specified in the following three ways
      - **Decimal number (base 10)**
        - It is defined by representing the digits between 0 to 9. Example: 1,3,65 etc
      - **Octal number (base 8)**
        - It is defined as a number in which 0 is followed by digits such as 0,1,2,3,4,5,6,7. Example: 032, 044, 065, etc
      - **Hexadecimal number (base 16)**
        - It is defined as a number in which 0x or 0X is followed by the hexadecimal digits (i.e., digits from 0 to 9, alphabetical characters from (a-f) or (A-F)) Example 0XFE oxfe

UE24CS151B : PSWC: Unit 1 - Literals and Constants in c Language

- **Literals** are the constant values assigned to the constant variables.
    - **Float literal**
        - It is a literal that contains only **floating-point** values or **real** numbers.
        - These real numbers contain the number of parts such as **integer part**, **real part**, **exponential part**, and **fractional part**.
        - The **floating-point literal** must be specified either in **decimal** or in **exponential** form.
            - **Decimal form**
                - The **decimal form** must contain either **decimal point**, **real part**, **or both**.
                - If it does not contain either of these, then the compiler will throw an error.
                - The decimal notation can be prefixed either by '+' or '-' symbol that specifies the positive and negative numbers.
                - Example: +9.5, -18.738

UE24CS151B : PSWC: Unit 1 - Literals and Constants in c Language

- **Literals** are the constant values assigned to the constant variables.
  - **Float literal**
    - The floating-point literal must be specified either in **decimal** or in **exponential** form.
      - **Exponential form**
        - The **exponential form** is useful when we want to represent the number, which is having a big magnitude.
        - It contains two parts, i.e., **mantissa** and **exponent**.
        - For example, the number is **3450000000000**, and it can be expressed as **3.45e12** in an exponential form

UE24CS151B : PSWC: Unit 1 - Literals and Constants in c Language

- **Literals** are the constant values assigned to the constant variables.
    - The floating-point literal must be specified either in decimal or in exponential form.
        - **Exponential form**
            - Syntax of float literal in **exponential form**
                - [+/-] <Mantissa> <e/E> [+/-] <Exponent>
            - Examples of real literal in exponential notation are
                - +3e24, -7e3, +3e-15
            - Rules for creating an **exponential notation**
                - In **exponential notation**, the **mantissa** can be specified either in **decimal** or **fractional** form
                - An **exponent** can be written in both **uppercase** and **lowercase**, i.e., **e** and **E**.
                - We can use both the signs, i.e., **positive** and **negative**, before the **mantissa** and **exponent**. Spaces are not allowed

UE24CS151B : PSWC: Unit 1 - Literals and Constants in c Language

- **Literals** are the constant values assigned to the constant variables.
    - **Character Literal**
        - A **character literal** contains a single character enclosed within single quotes.
        - If we try to store more than one character in a character literal, then the warning of a multi-character character constant will be generated.
        - Representation of **character literal**
            - A **character literal** can be represented in the following ways:
                - It can be represented by specifying a single character within single quotes. For example, 'x', 'y', etc.
                - We can specify the escape sequence character within single quotes to represent a character literal. For example, '\n', '\t', '\b'.
                - We can also use the **ASCII** in integer to represent a character literal. For example, the ascii value of 65 is 'A'.
                - The octal and hexadecimal notation can be used as an escape sequence to represent a character literal. For example, '\043', '\0x22'.

- **Literals** are the constant values assigned to the constant variables.
  - **String** Literal
    - A **string** literal represents multiple characters enclosed within double-quotes
    - It contains an additional character, i.e., '\0' (null character), which gets automatically inserted.
    - This **null** character specifies the **termination** of the **string**.

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CELEBRATING 50 YEARS

UE24CS151B
End of Slot #4, #5, #6

Nitin V Pujari
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For Course Digital Deliverables visit www.pesuacademy.com

Problem Solving With C - UE24CS151B

Variables and Data Types

Prof. Sindhu R Pai
PSWC Theory Anchor, Feb-May, 2025
Department of Computer Science and Engineering

PROBLEM SOLVING WITH C

Variables and Data Types

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1. Identifiers
2. Variable declaration, definition and initialization
3. Keywords
4. Data types

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Identifiers

- It is a name used to identify a variable, keyword, function, or any other user-defined item.
- Starts with a letter A to Z, a to z, or an underscore '_' followed by zero or more letters, underscores, and digits (0 to 9)
- C does not allow few punctuation characters such as #, @ and % within identifiers

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Variable declaration, definition and initialization

- Variable is a name given to a storage area that a code can manipulate
- Has a **name, location, type, life, scope and qualifiers**
- Variable declaration and definition: int a; //An uninitialized variable has some undefined value. A variable can be assigned a value later in the code
- Variable initialization: int a = 10;

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Keywords

- Are identifiers which have special meaning in C.
- Cannot be used as constants or variables
- Few here: auto, else, long, switch, break, enum, case, extern, return char, float, for, void, sizeof, int, double …
- int auto = 10; // Error

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Data Types

- The amount of storage to be reserved for the specified variable.
- Significance of types: **Memory allocation, Range of values allowed, Operations bound to this type, Type of data to be stored**
- Categories: Primary → int, float, double and char
  Secondary → Derived(Arrays) and User defined(struct, enum, union and typedef)
- sizeof(short int)<=sizeof(int)<=sizeof(long int)<=sizeof(long long int)<= sizeof(float)<=sizeof(double)<=sizeof(long double)
- Coding examples on Range of values using limits.h

THANK YOU

Department of Computer Science and Engineering

Dr. Shylaja S S, Director, CCBD & CDSAML, PESU
Prof. Sindhu R Pai - sindhurpai@pes.edu

Ack: Teaching Assistant - U Shivakumar

Problem Solving With C - UE24CS151B

Qualifiers in C

Prof. Sindhu R Pai
PSWC Theory Anchor, Feb-May, 2025
Department of Computer Science and Engineering

PROBLEM SOLVING WITH C

Qualifiers in C

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1. Introduction
2. Size Qualifiers
3. Sign Qualifiers
4. Type Qualifiers
5. Applicability of Qualifiers to Basic Types

Qualifiers in C

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Introduction

- Keywords which are applied to the data types resulting in Qualified type
- Applied to basic data types to alter or modify its sign or size

- Types of Qualifiers
  - **Size Qualifiers**
  - **Sign Qualifiers**
  - **Type qualifiers**

Qualifiers in C

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Size Qualifiers

- Prefixed to **modify the size of a data type** allocated to a variable
- Supports two size qualifiers, **short** and **long**
- Rules Regarding size qualifier as per ANSI C standard
  - **short int <= int <=long int //** short int may also be abbreviated as short and long int as long. But, there is no abbreviation for long double.
- Coding Examples

Qualifiers in C

Sign Qualifiers

- Used to specify the signed nature of integer types
- It specifies whether a variable can hold a negative value or not
- Sign qualifiers are used with int and char types
- There are two types of Sign Qualifiers in C. **Signed** and **Unsigned**
- A **signed qualifier** specifies a variable which can hold both positive and negative integers
- An **unsigned qualifier** specifies a variable with only positive integers
- Coding Examples

Qualifiers in C

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Type Qualifiers

- A way of expressing additional information about a value through the type system and ensuring correctness in the use of the data

- Type Qualifiers consists of two keywords
  - **const**
  - **volatile.**

Qualifiers in C

Type Qualifiers continued..

- **const:**
  - Once defined, their values cannot be changed.
  - Called as literals and their values are fixed.
  - **Syntax: const data_type variable_name**
- **volatile:**
  - Intended to prevent the compiler from applying any optimizations
  - Their values can be changed by code outside the scope of current code at any time
  - Also can be changed by any external device or hardware
  - **Syntax: volatile data_type variable_name**
- Coding Examples

Qualifiers in C

Applicability of Qualifiers to Basic Types

No.	Data Type	Qualifier
1.	char	signed, unsigned
2.	int	short, long, signed, unsigned
3.	float	No qualifier
4.	double	long
5.	void	No qualifier

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Problem Solving With C - UE24CS151B

Simple Input/Output

Prof. Sindhu R Pai
PSWC Theory Anchor, Feb-May, 2025
Department of Computer Science and Engineering

Simple Input/Output

1. Formatted output function
2. Formatted input function
3. Unformatted functions

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Formatted output function – printf()

- int printf(const char *format, ...)
- Predefined function in stdio.h
- Sends formatted output to stdout by default
- Output is controlled by the first argument
- Has the capability to evaluate an expression
- On success, it returns the number of characters successfully written on the output.
- On failure, a negative number is returned.
- Arguments to printf can be expressions
- Coding examples

Simple Input/Output

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Format string

- % [flags] [field_width] [.precision] conversion_character
  where components in brackets [] are optional. The minimum requirement is % and a conversion character (e.g. %d).

- %d, %x, %o, %f, %c, %p, %lf, %s

- Coding examples

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Escape sequences

- Represented by two key strokes and represents one character
- \n, \t, \r, \a, \", \', \\, \b
- Coding examples

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Formatted input function – scanf()

- int scanf(const char *format, ...)
- Predefined function in stdio.h
- & : Address operator is compulsory in scanf for all primary types
- Reads formatted input using stdin. By default keyboard
- This function returns the following value
  - >0 — The number of items converted and assigned successfully.
  - 0 — No item was assigned.
  - <0 — Read error encountered or end-of-file (EOF) reached before any assignment was made
- Coding examples

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Unformatted functions

- Character input and output functions – **getchar()** and **putchar()**
- String input and output functions – **gets()** and **puts()** This will be discussed in unit – 2
- Coding examples

THANK YOU

Department of Computer Science and Engineering

Dr. Shylaja S S, Director, CCBD & CDSAML, PESU
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UE23CS151B: Problem Solving with C
Lecture Slides - Slot #7, #8

Nitin V Pujari
Faculty, Computer Science
Dean - IQAC, PES University

UE23CS151B: Problem Solving with C - Syllabus

Unit 1 : Problem Solving Fundamentals - 14 Hours - 18 Slots

Introduction to Programming, Salient Features of 'C', Program Structure, Variables, Data Types & range of values, Operators and Expressions, Control Structures, Input/ Output Functions, Language Specifications - Behaviors, Single character input and output

Unit 2 : Counting, Sorting and Searching - 14 Hours - 18 Slots

Arrays – 1D and 2D, Pointers, Arrays with Pointers, Functions, Storage classes, Recursion, Enums, Bit Fields

Unit 3 : Text Processing and User-Defined Types 14 Hours - 18 Slots

Strings, String Manipulation Functions & Errors, Dynamic Memory Management functions & errors, Structures, #pragma, Unions, Lists, Priority Queue

Unit 4 : File Handling and Portable Programming - 14 Hours - 18 Slots

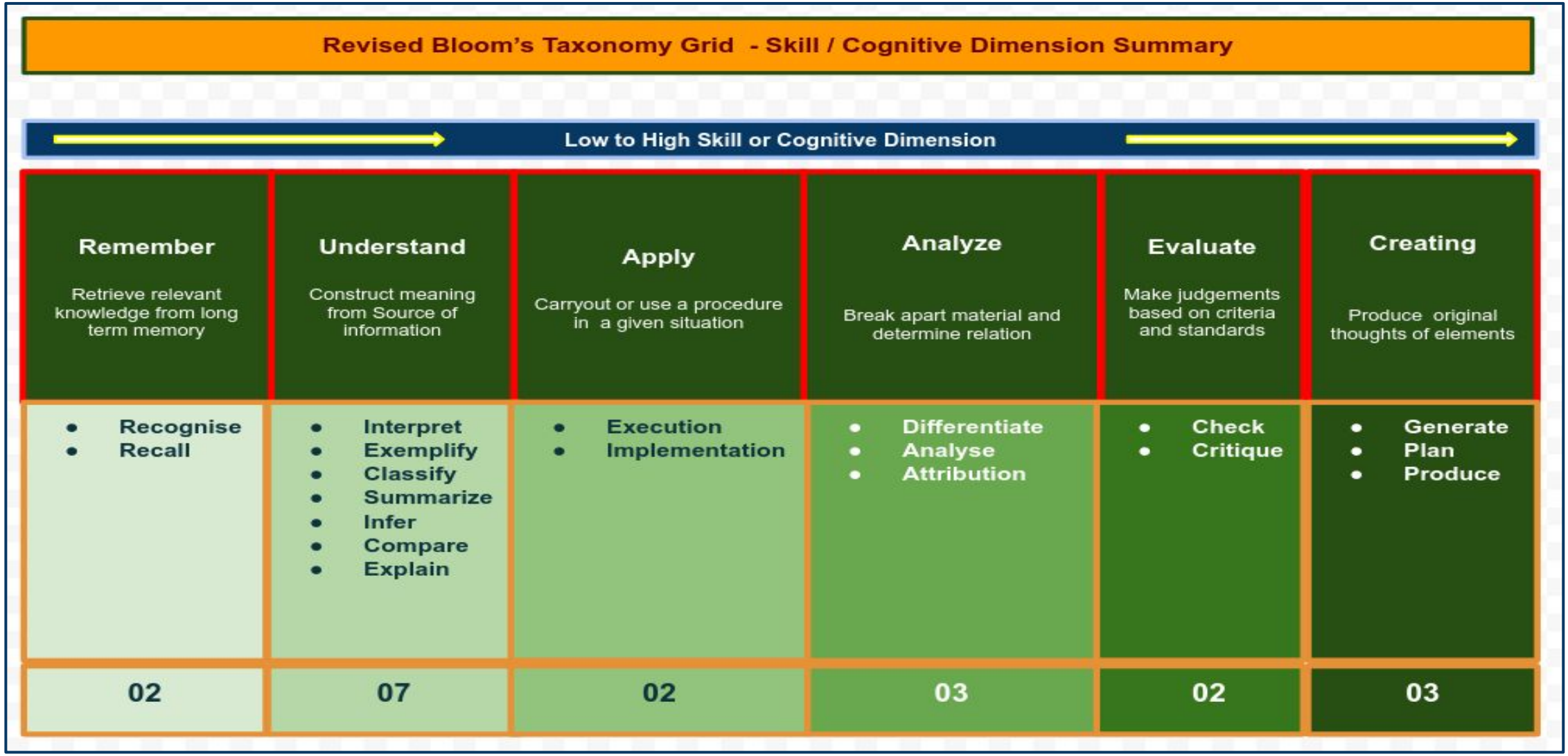
File IO using redirection, File Handling functions, Callback, Searching, Sorting, Preprocessor Directives, Conditional Compilation and Code Review, Debugging with GDB

UE23CS151B: Problem Solving with C - Course Objectives

The objective(s) of this course is to make students

- **CObj 1: Acquire knowledge on how to solve relevant and logical problems using computing machine**
- **CObj 2: Map algorithmic solutions to relevant features of C programming language constructs**
- **CObj 3: Gain knowledge about C constructs and its associated ecosystem**
- **CObj 4: Appreciate and gain knowledge about the issues with C Standards and its respective behaviours**

Bloom's Taxonomy



Revised Bloom's Taxonomy Grid - Skill / Cognitive Dimension Summary

Low to High Skill or Cognitive Dimension

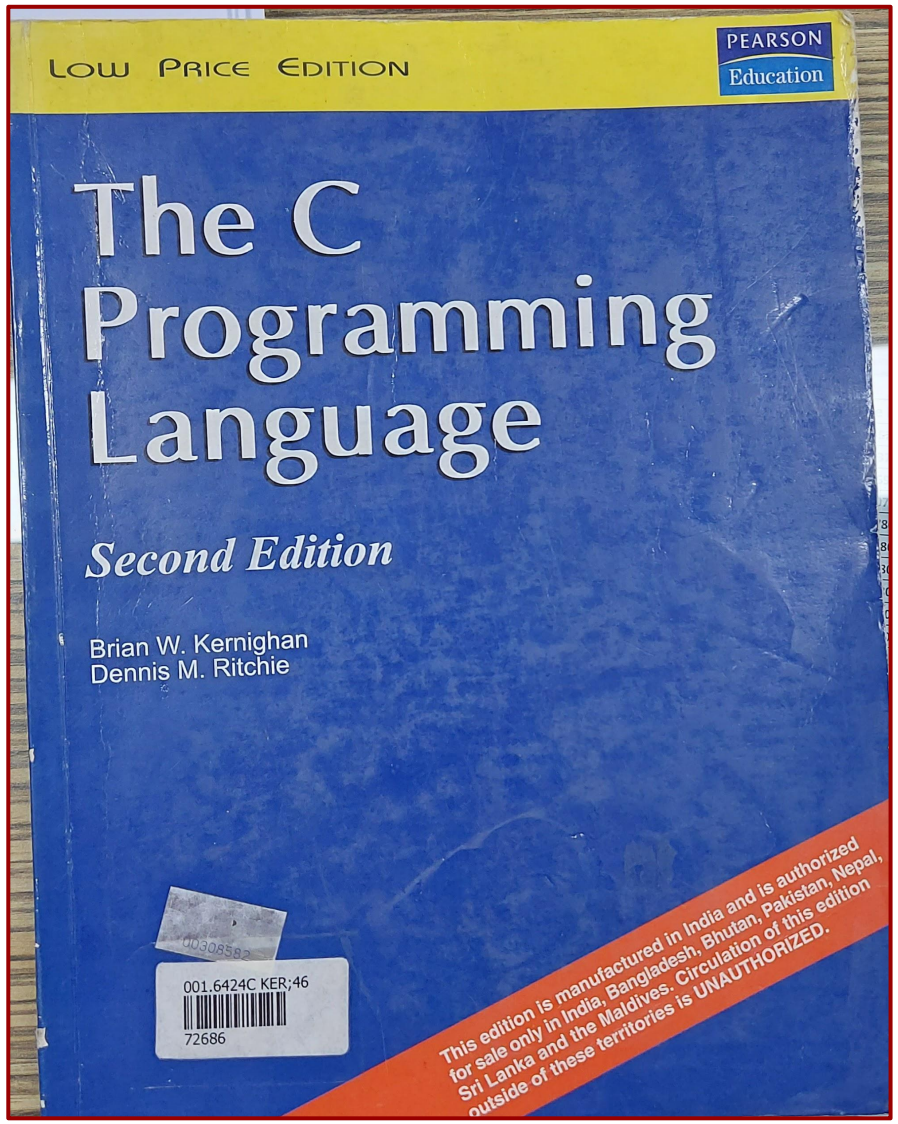
Remember	Understand	Apply	Analyze	Evaluate	Creating
Retrieve relevant knowledge from long term memory	Construct meaning from Source of information	Carryout or use a procedure in a given situation	Break apart material and determine relation	Make judgements based on criteria and standards	Produce original thoughts of elements
• Recognise • Recall	• Interpret • Exemplify • Classify • Summarize • Infer • Compare • Explain	• Execution • Implementation	• Differentiate • Analyse • Attribution	• Check • Critique	• Generate • Plan • Produce
02	07	02	03	02	03

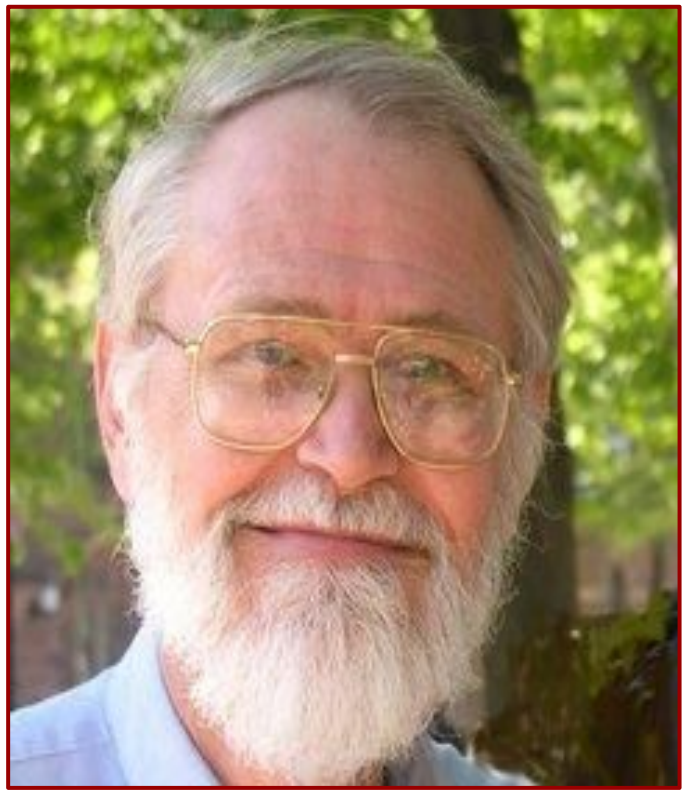
UE23CS151B: Problem Solving with C - Course Outcomes

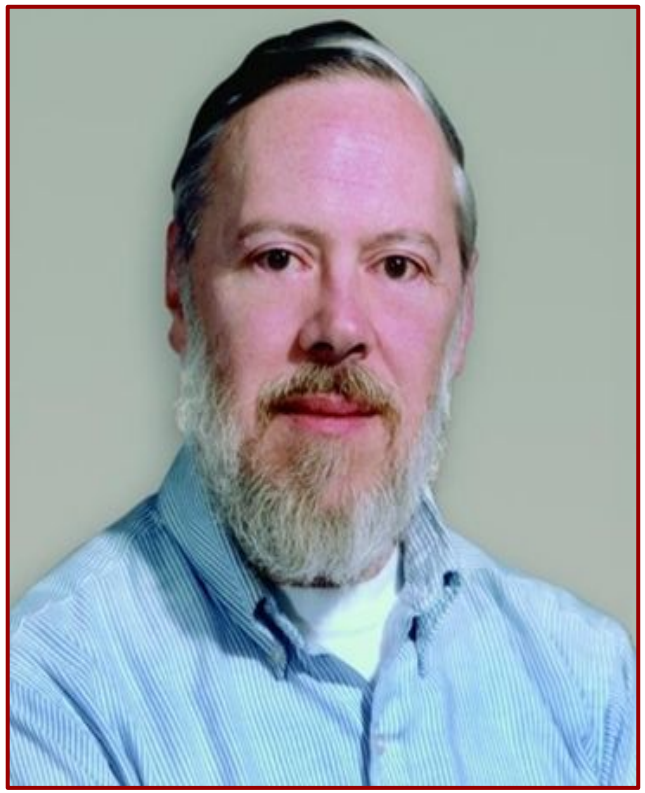
At the end of the course, the student will be able to

- CO1: Understand and Apply algorithmic solutions to basic problems using appropriate C constructs
- CO1: Understand and Apply Sorting and Searching techniques
- CO3: Understand, Analyse and Apply text processing and string manipulation methods using Arrays, Pointers and functions
- CO4: Understand prioritized scheduling and Implement the same using C structures using advanced C constructs, preprocessor directives and conditional compilation

UE22CS151B: Problem Solving with C Text Book







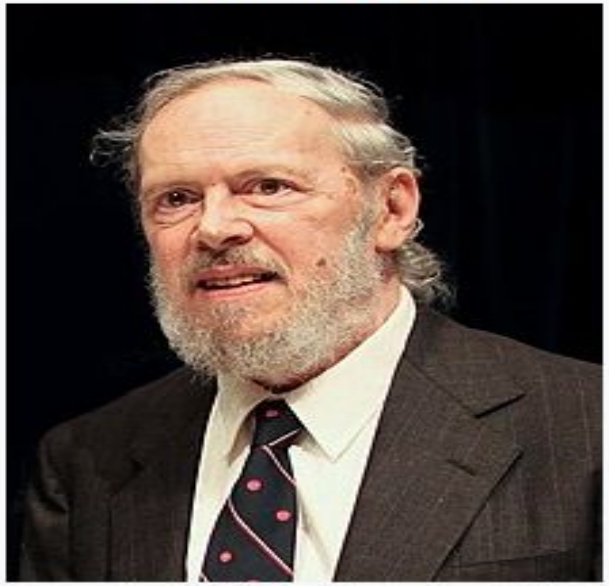
UE22CS151B: About Text Book Authors

Brian Kernighan

Brian Kernighan at Bell Labs in 2012

Born	Brian Wilson Kernighan 1942 (age 79–80)[1] Toronto, Ontario, Canada
Nationality	Canadian
Citizenship	Canada
Alma mater	University of Toronto (BASc) Princeton University (PhD)

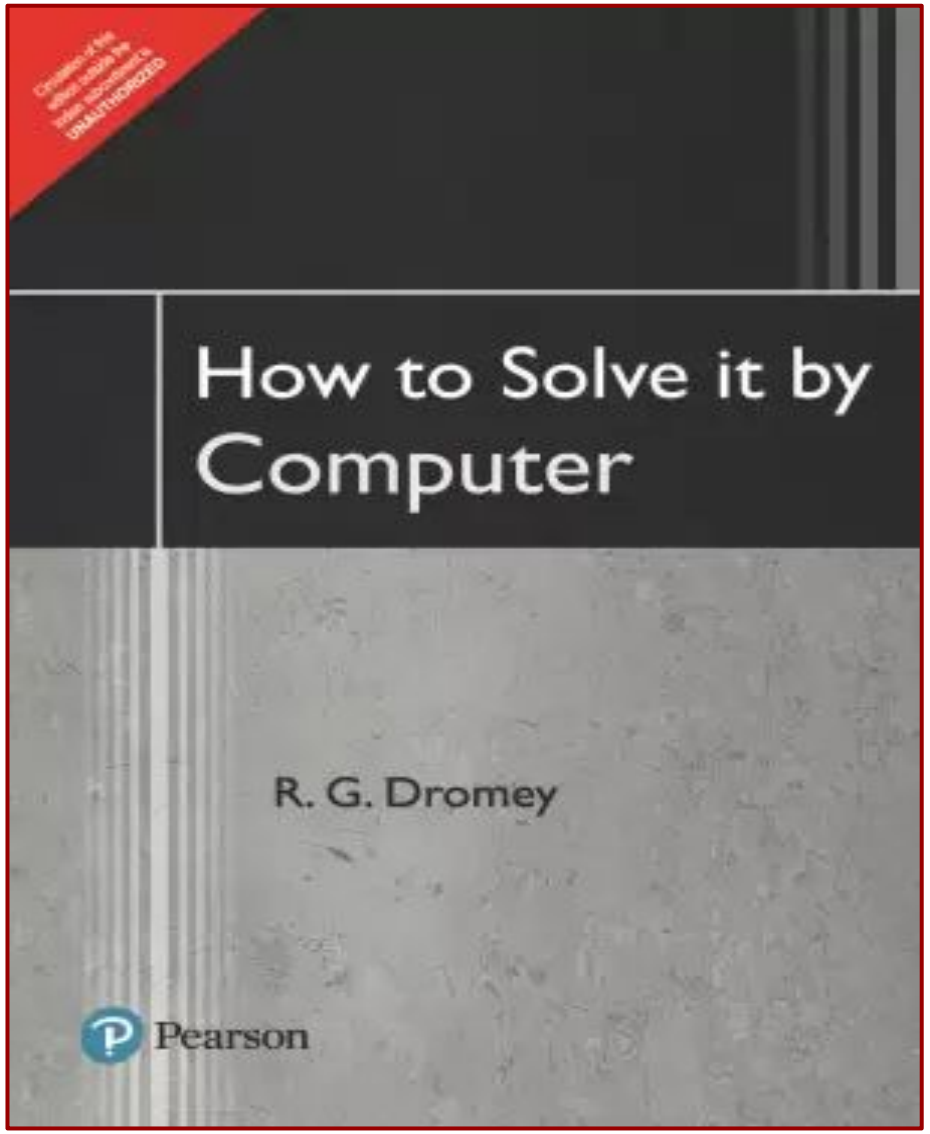
Dennis Ritchie

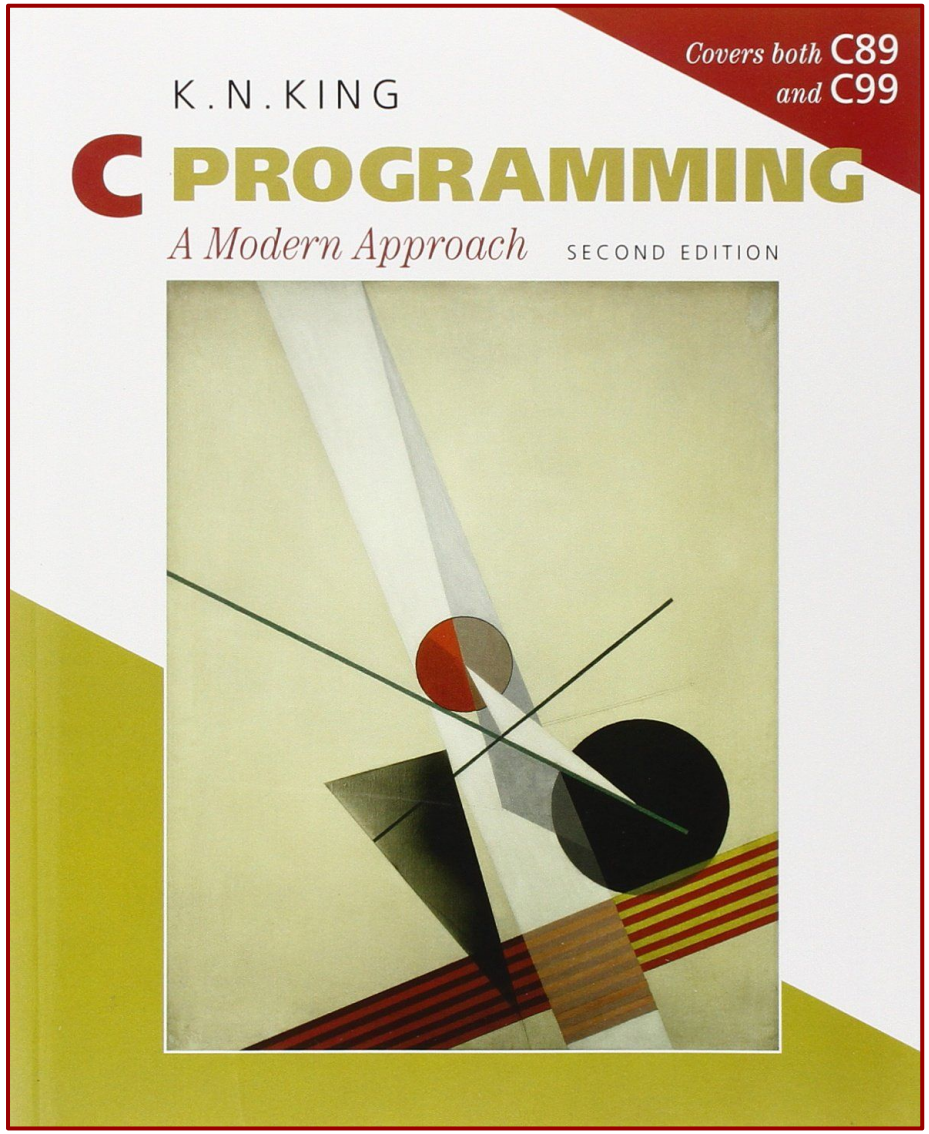


Dennis Ritchie at the Japan Prize Foundation in May 2011

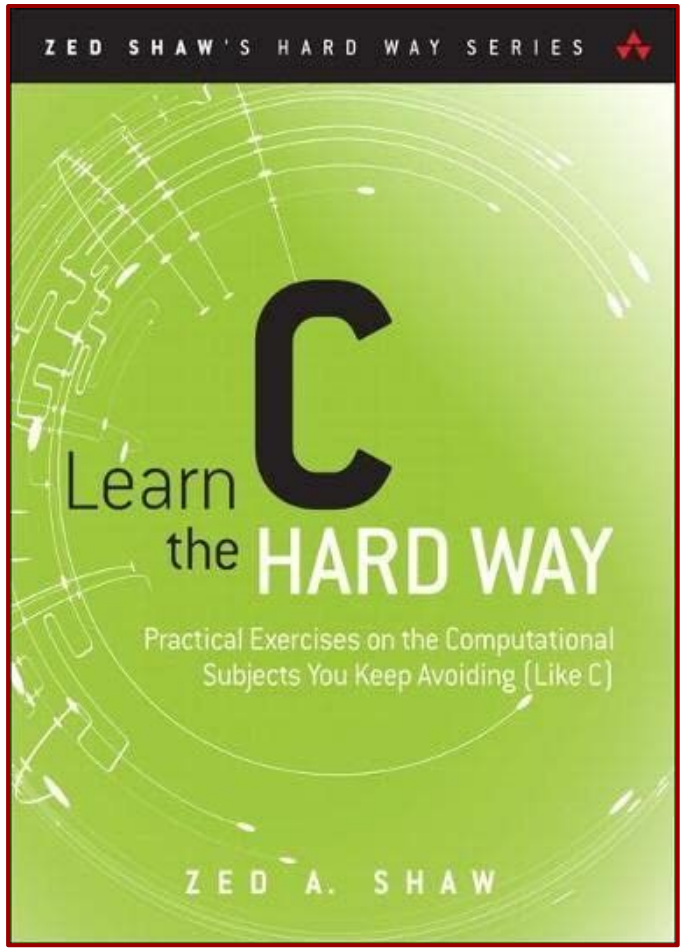
Born	September 9, 1941[1][2][3][4] Bronxville, New York, U.S.
Died	c. October 12, 2011 (aged 70) Berkeley Heights, New Jersey, U.S.
Nationality	American
Alma mater	Harvard University (Ph.D., 1968)

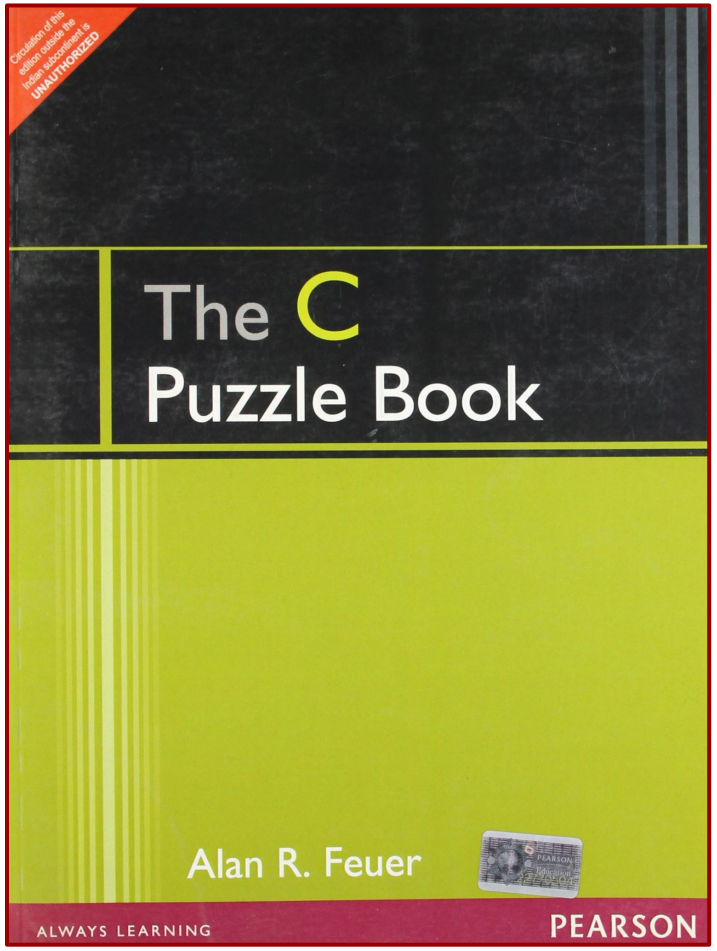
UE22CS151B: Problem Solving with C Reference Books

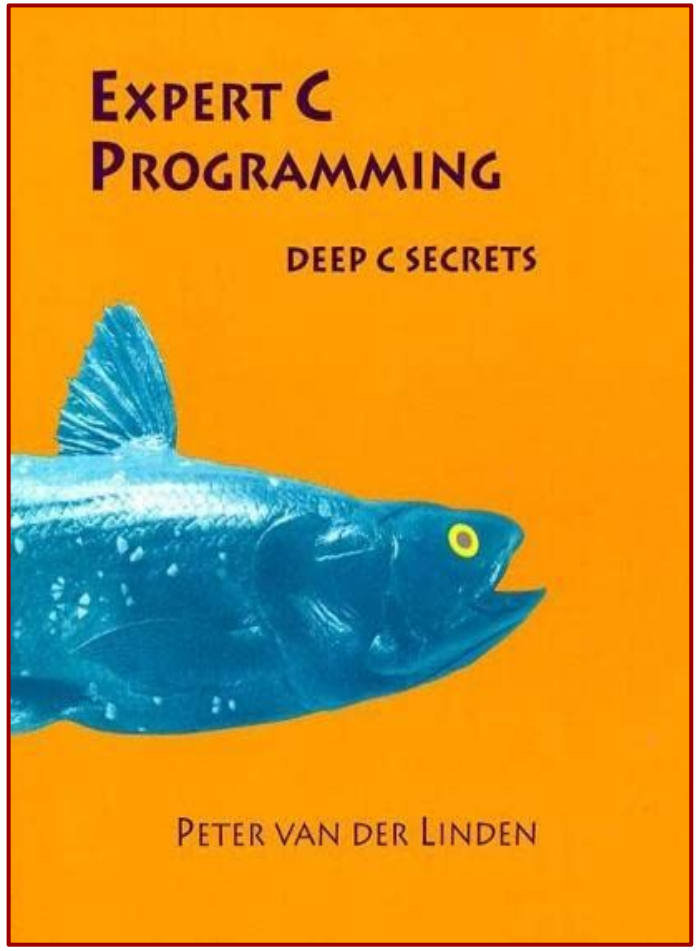




UE22CS151B: Problem Solving with C Reference Books







Week No.	Month	Day						No. of working days	Activities/Events
		Mon	Tue	Wed	Thu	Fri	Sat		
1.	Feb				8	9	10	5	Class commencement and Course registration
2.	Feb		13	**14**	15	16	17	5	
3.	Feb	19	20	21	22	**23**	24	5	
4.	Feb/Mar	26	**27**	28 **FAM I**	29	**1**	2	5	
5.	Mar	4	5	6	7	**8 H**	9	4	8th-Maha Shivaratri
6.	Mar	11	12	13 **CCM I**	14	15	16	5	
7.	Mar	18 **ISA 1**	19 **ISA 1**	20 **ISA 1**	21 **ISA 1**	22 **ISA 1**	23	5	ISA 1 Week(Units I & II)
8.	Mar	25	26	27	28	29 **AT**	30 **AT**	4	AT- Aatmatisha,The Annual Techno cultural Fest
9.	Apr	1	2	3	4	5	6 **PTM I**	5	
10.	Apr	8	**9 H**	10	**11 H**	12	13	3	9th – Chandramana Ugadi 11th - Ramzan
11.	Apr	15	16	17	18	19	20	5	
12.	Apr	22	23	24 **FAM II**	25	26	27	5	
13.	Apr/May	29	30	**1 H**	2	3	4	4	1st- May Day
14.	May	6	7	8	9	10	11	5	
15.	May	13	14	15 **CCM II**	16	17	18	5	
16.	May	20	21	22	23	24	25	5	
17.	May/Jun	27 **ISA 2**	28 **ISA 2**	29 **ISA 2**	30 **ISA 2**	31 **ISA 2 LWD**	1 **PTM II**	5	ISA 2 Week(Units III & IV)
18.	Jun	3	4 **FASD**	5	6	7	8		END SEMESTER ASSESSMENT (6th Jun-21st Jun) 18th-Bakrid
19.	Jun	10	11	12	13	14	15		
20.	Jun	17	**18 H**	19	20	21	22		

FAM: Faculty Advisor Meeting
CCM: Class Committee Meeting

FASD: Final Attendance Status Display
PTM: Parent Teachers Meeting

LWD: Last working Day
ISA : In Semester Assessment

Announcement of Results: July 02, 2024
Commencement of next Semester: August 05 2024

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Slot #7, #8

12.2.2024

UE23CS151B : PSWC: Unit 1

- **Literals** are the constant values assigned to the **constant** variables.
- There are **four** types of literals that exist in c programming:
  - **Integer literal**
    - It is a numeric literal that represents only integer type values.
    - It represents the value neither in fractional nor exponential part.
    - It can be specified in the following three ways
      - **Decimal number (base 10)**
        - It is defined by representing the digits between 0 to 9. Example: 1,3,65 etc
      - **Octal number (base 8)**
        - It is defined as a number in which 0 is followed by digits such as 0,1,2,3,4,5,6,7. Example: 032, 044, 065, etc
      - **Hexadecimal number (base 16)**
        - It is defined as a number in which 0x or 0X is followed by the hexadecimal digits (i.e., digits from 0 to 9, alphabetical characters from (a-f) or (A-F)) Example 0XFE oxfe

- **Literals** are the constant values assigned to the constant variables.
    - **Float literal**
        - It is a literal that contains only **floating-point** values or **real** numbers.
        - These real numbers contain the number of parts such as **integer part**, **real part**, **exponential part**, and **fractional part**.
        - The **floating-point literal** must be specified either in **decimal** or in **exponential** form.
            - **Decimal form**
                - The **decimal form** must contain either **decimal point**, **real part**, **or both**.
                - If it does not contain either of these, then the compiler will throw an error.
                - The decimal notation can be prefixed either by '+' or '-' symbol that specifies the positive and negative numbers.
                - Example: +9.5, -18.738

- **Literals** are the constant values assigned to the constant variables.
    - **Float literal**
        - The floating-point literal must be specified either in **decimal** or in **exponential** form.
            - **Exponential form**
                - The **exponential form** is useful when we want to represent the number, which is having a big magnitude.
                - It contains two parts, i.e., **mantissa** and **exponent**.
                - For example, the number is **3450000000000**, and it can be expressed as **3.45e12** in an exponential form

UE23CS151B : PSWC: Unit 1

- **Literals** are the constant values assigned to the constant variables.
    - The floating-point literal must be specified either in decimal or in exponential form.
        - **Exponential form**
            - Syntax of float literal in **exponential form**
                - [+/-] <Mantissa> <e/E> [+/-] <Exponent>
            - Examples of real literal in exponential notation are
                - +3e24, -7e3, +3e-15
            - Rules for creating an **exponential notation**
                - In **exponential notation**, the **mantissa** can be specified either in **decimal** or **fractional** form
                - An **exponent** can be written in both **uppercase** and **lowercase**, i.e., **e** and **E**.
                - We can use both the signs, i.e., **positive** and **negative**, before the **mantissa** and **exponent**. Spaces are not allowed

UE23CS151B : PSWC: Unit 1

- **Literals** are the constant values assigned to the constant variables.
    - **Character Literal**
        - A **character literal** contains a single character enclosed within single quotes.
        - If we try to store more than one character in a character literal, then the warning of a multi-character character constant will be generated.
        - Representation of **character literal**
            - A **character literal** can be represented in the following ways:
                - It can be represented by specifying a single character within single quotes. For example, 'x', 'y', etc.
                - We can specify the escape sequence character within single quotes to represent a character literal. For example, '\n', '\t', '\b'.
                - We can also use the **ASCII** in integer to represent a character literal. For example, the ascii value of 65 is 'A'.
                - The octal and hexadecimal notation can be used as an escape sequence to represent a character literal. For example, '\043', '\0x22'.

UE23CS151B : PSWC: Unit 1

- **Literals** are the constant values assigned to the constant variables.
  - **String** Literal
    - A **string** literal represents multiple characters enclosed within double-quotes
    - It contains an additional character, i.e., '\0' (null character), which gets automatically inserted.
    - This **null** character specifies the **termination** of the **string**.

UE23CS151B : PSWC: Unit 1

- The **sizeof** operator is the most common operator in C.
- It is a **compile-time unary operator** and is used to compute the size of its operand.
- It **doesn't execute** (run) the **code** inside ()
- It returns the size of a variable.
- It can be applied to any data type, float type, pointer type variables
- When **sizeof()** is used with the data types, it simply returns the amount of memory allocated to that data type.
- The output can be different on **different machines** like a **32-bit system** can show different output while a **64-bit system** can show different of same data types

UE23CS151B : PSWC: Unit 1

- Input and output functions are available in the **c language** to perform the most common tasks.
- In every **c program**, three basic functions take place namely **accepting of data as input**, **the processing of data**, and **the generation of output**
- When a **programmer** says **input**, it would mean that they are **feeding** some **data** in the program.
- Programmer can give this **input** from the **command line** or **in the form of any file**.
- The **c programming language** comes with a set of various **built-in functions** for **reading** the **input** and then **feeding** it to the available program as per our requirements.
- When a **programmer** says **output**, they mean **displaying** some **data** and **information** on the **printer**, the **screen**, or any other **file**.
- The **c programming language** comes with various **built-in functions** for **generating** the **output** of the **data** on any **screen** or **printer**, and also redirecting the output in the form of binary files or text file.

UE23CS151B : PSWC: Unit 1

- The **unformatted functions** are **not capable** of **controlling** the **format** that is involved in **writing** and **reading** the available **data**.
- Hence **these functions** constitute the most **basic** forms of **input** and **output**.
- The supply of input or the display of output **isn't allowed** in the **user format**, hence we call these functions as **unformatted functions** for **input** and **output**.
- The unformatted input-output functions further have two categories:
    - The **character** functions
        - We use the character input functions for reading only a single character from the input device by default the keyboard
            - **getchar(), getche(),** and the **getch()** refer to the **input functions** of **unformatted type**
        - We use the character output functions for writing just a single character on the output source by default the screen
            - the **putchar()** and **putch()** refer to the output functions of unformatted type

UE23CS151B : PSWC: Unit 1

- The **unformatted functions** are **not capable** of **controlling** the **format** that is involved in **writing** and **reading** the available **data**.
- Hence **these functions** constitute the most **basic** forms of **input** and **output**.
- The supply of input or the display of output **isn't allowed** in the **user format**, hence we call these functions as **unformatted functions** for **input** and **output**.
- The unformatted input-output functions further have two categories:
    - The **string** functions
        - In any programming language including c, the **character array** or **string** refers to the **collection** of various **characters**
        - Various types of **input and output** functions are present in **c programming** that can easily read and write these strings.
            - The **puts()** and **gets()** are the most commonly used ones for **unformatted** forms
            - **gets()** refers to the **input** function used for **reading** the **string** characters
            - **puts()** refers to the **output** function used for **writing** the **string** characters

- **printf()**
  - This function is used to display one or multiple values in the output to the user at the console.
    - int printf(const char *format, ...)
    - Predefined function in stdio.h
    - Sends formatted output to stdout by default
    - Output is controlled by the first argument
    - Has the capability to evaluate an expression
    - On success, it returns the number of characters successfully written on the output.
    - On failure, a negative number is returned.
    - Arguments to printf can be expressions
  - While calling any of the formatted console input/output functions, we must use a specific format specifiers in them, which allow us to read or display any value of a specific primitive data type.
  - % [flags] [field_width] [.precision] conversion_character where components in brackets [] are optional.
  - The minimum requirement is % and a conversion character (e.g. %d)
    - %d, %x, %o, %f, %c, %p, %lf, %s

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- **Error**
  - a mistake
  - the state or condition of being wrong in conduct or judgement
  - a measure of the estimated difference between the observed or calculated value of a quantity and its true value
- **Preprocessor Error**
  - #error is a preprocessor directive in c which is used to raise an error during compilation and terminate the process

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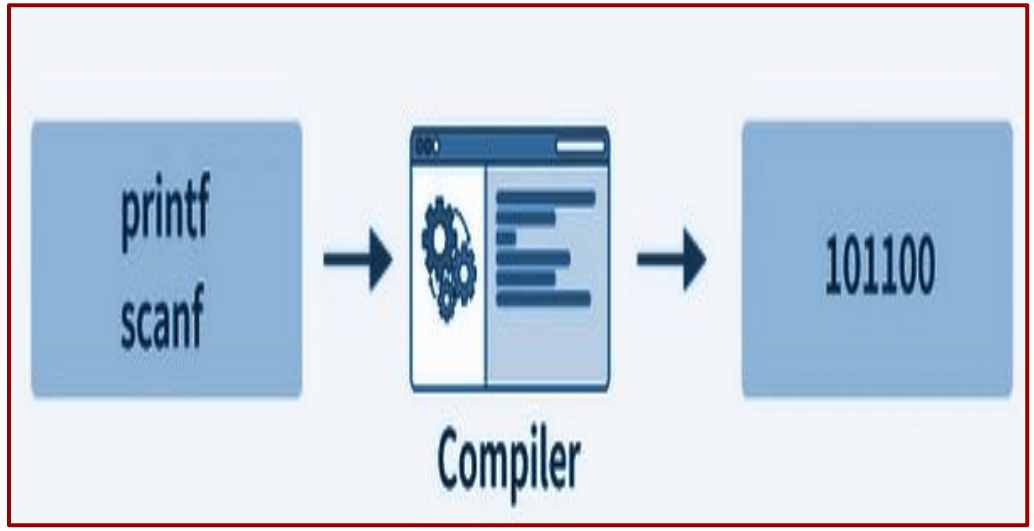
- **Compile time** is the period when the programming code is converted to the machine code.

- **Runtime** is the period of time when a program is running and generally occurs after compile time



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Compile-time error	Run-time error
These errors are detected during the compile-time	These errors are detected at the run-time
Compile-time errors do not let the program be compiled	Programs with run-time errors are compiled successfully but an error is encountered when the program is executed
Errors are detected during the compilation of the program	Errors are detected only after the execution of the program
Compile-time errors can occur because of wrong syntax or wrong semantics	Run-time errors occur because of absurd operations

- **Compile time Error**
  - When the programmer does not follow the syntax of any programming language, then the compiler will throw the **Syntax Error**, such errors are also called **Compile Time Error**
  - **Syntax Errors** are easy to figure out because the compiler highlights the line of code that caused the error.

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- **Linker Error**
  - **Linker** is a program that takes the object files generated by the compiler and combines them into a single executable file.
  - **Linker Errors** are the errors encountered when the executable file of the code can not be generated even though the code gets compiled successfully.
  - This **Error** is generated when a different object file is unable to link with the main object file.
  - We can run into a linked error if we have imported an incorrect header file in the code

- **Runtime Error**
  - Errors that occur during the execution (or running) of a program are called **Runtime Errors.** These errors occur after the program has been compiled and linked successfully.
  - When a program is running, and it is not able to perform any particular operation, it means that we have encountered a runtime error.

- **Logical Error**
  - Sometimes, we do not get the output we expected after the compilation and execution of a program.
  - Even though the code seems error free, the output generated is different from the expected one.
  - These types of errors are called **Logical Errors**.
- **Semantic Errors**
  - Errors that occur because the compiler is unable to understand the written code are called Semantic Errors.
  - A semantic error will be generated if the code makes no sense to the compiler, even though it is syntactically correct.
  - It is like using the wrong word in the wrong place in the English language

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Keywords in C Programming			
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

There are **32** keywords in c Language

Keyword Coverage
7 of 32
21.88%

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CELEBRATING 50 YEARS

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Problem Solving With C - UE24CS151B

Operators in C

Prof. Sindhu R Pai
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PROBLEM SOLVING WITH C

Operators in C

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1. Operators and its Classification
2. Expression
3. Sequence point operation

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Operator and its Classification

- Operator is a symbol used for calculations or evaluations
- Has rank, precedence and Associativity
- Classification: Based on the operation:

Arithmetic – Increment(++) & Decrement(--)

Relational - >, <, <=, >=, ==, !=

Logical(short circuit evaluation) - &&, ||, !

Bitwise - &, |, ~, ^, <<, >>

Address - &

Dereferencing Operator - *

Based on the operands: Unary, Binary, Ternary

Operators in C

Expression

- An expression consists of Operands and Operators
- Evaluation of Operands: Order is not defined
- Evaluation of Operators: Follows the rules of precedence and rules of Associativity

  http://web.cse.ohio-state.edu/~babic.1/COperatorPrecedenceTable.pdf
- L-value and R-values.
- Side effects of Expression
- Coding examples

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Sequence point Operation

- Specifies points in the code beyond which all side effects will definitely be complete
- Beyond this, any variable can be used with no ambiguity
- Coding examples with &&

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Control Structures

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PROBLEM SOLVING WITH C

Control Structures

1. Selection structures
2. Looping structures
3. Nested Control Structures
4. Practice Programs

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Selection Structures

- If

```
if (e1)
    <block>|<stmt>
```

- If – else

```
if (e1)
    <block>|<stmt>
else
    <block>|<stmt>
```

- If – else if – else if – else

```
if (e1)
    <block>|<stmt>
else if (e2)
    <block>|<stmt>
else
    <block>|<stmt>
```

- Switch

```
switch (expression)
{
        case integral constant: <stmt> break;
        case integral constant: <stmt> break;
        default: <stmt>
}
```

- Coding Examples

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Looping Structures

- for

```
for(e1; e2; e3)
        <block>|<stmt>
```

- while

```
while(e2)
        <block>|<stmt>
```

- do while

```
do {    <block>
}while(e2);
```

e1,e2,e3 are expressions where e1: initialization, e2: condition, e3: modification

- Infinite loop
- Coding Examples

Nested Control structures

- One loop may be inside another
- One if may be inside another: inner if is reached only if the Boolean condition of the outer if is true
- Combination of above two
- Coding Examples

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Practice Programs

- WAP to count the number of digits in a given integer.
- WAP to count the number of digits which are divisible by 2 in a given integer.
- WAP to input a floating point number from the user and print the count of digits which are divisible by 3 after the decimal point.
- Input 10 characters from the user and check the count of vowels and print same.

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Single character Input Output

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Single character Input Output

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Few points to discuss !!

- Storing more than one value in single variable of primitive type - Possible?
- Code for Real World applications developed by one person or by a Team?
- You Tube code is written in one language and that code is available in one file?

PROBLEM SOLVING WITH C

Single character Input Output

- Character refers to a single input - Occupies a single byte.
- English alphabets A as 65, B as 66, Z as 90, a as 97 and so on in a coding scheme called ASCII.
- C treats all the devices as files. Following three files are automatically opened when a program executes to provide access to the keyboard and screen.

Standard File	File Pointer	Device
Standard Input	`stdin`	Keyboard
Standard Output	`stdout`	Screen
Standard Error	`stderr`	Screen

Single character Input Output

- **Approaches:**
  - **scanf and printf** – Formatted IO functions
  - **getchar and putchar** - Commonly used in console applications or loops for handling text input and output efficiently
    - The getchar reads a single character from the standard input (stdin) and returns it as an int, allowing it to handle **ASCII values** or detect **EOF (End of File)**. It waits for the user to press **Enter** before processing the input.
    - putchar() is used to print a single character to the standard output (stdout). It takes a character as an argument and displays it on the screen, making it useful for character-by-character output.
- **Coding examples**

Single character Input Output

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- **Approaches:**
  - **getc() and putc()**
    - getc reads a character from an input stream and returns the corresponding integer value on success. It returns EOF on failure.

      int getc(FILE *stream)
    - putc writes a character into a file

      int putc(int character, FILE *stream)
- **Coding examples**

Single character Input Output

- **Approaches: Non-standard IO functions**
  - **getch() and getche()** - Reads a character from the keyboard and copies it into memory area. getch() function, the typed character will not be echoed(displayed) on the screen and in getche() function the typed character will be echoed(displayed) on the screen.
  - putch() - Outputs a character stored in the memory using a variable on the output screen.
- **Coding examples**

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Problem Solving With C - UE24CS151B

Language Specifications/Behaviors

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PROBLEM SOLVING WITH C

Language Specifications/Behaviors

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1. Language Specification
2. Standards
3. Behaviors defined by C Standards
4. Undefined Behavior in detail

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Language Specification

- A documentation that defines a programming language so that users and implementers can agree on what programs in that language mean.

- Are typically detailed and formal, and primarily used by implementers referring to them in case of ambiguity.

- Can take several forms:

  An explicit definition of the syntax and semantics of the language.

  A description of the behavior of a "translator" for the language

  "Model implementation" is a program that implements all requirements from a corresponding specification

Language Specifications/Behaviors

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Standards

de Facto: Practices that are legally recognized, regardless of whether the practice exists in reality.

de Jure: Describes situations that exist in reality, even if not legally recognized

- Language may have one or more implementations which acts as deFacto Language may be implemented and then specified, or vice versa or together.
- Languages can exist and be popular for decades without a specification - Perl
- After 20 years of usage, specification for PHP in 2014
- ALGOL 68 : First (and possibly one of the last) major language for which a full formal definition was made before it was implemented

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Behaviors defined by C Standards

- Locale-specific behavior - Not discussed here
- Unspecified behavior - Order of evaluation of arguments in printf function
- Implementation-defined behavior – Size of each type
- Undefined behavior in detail

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Undefined Behavior in detail

- The result of executing a program whose behavior is prescribed to be unpredictable in the language specification to which the computer code adheres.
- It is the name of a list of conditions that the program must not meet.
- Examples: Memory access outside of array bounds, Signed integer overflow
- Standard imposes no requirements: May fail to compile, may crash, may generate incorrect results, may fortunately do what exactly programmer intended
- Coding Examples

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