

# **FEEG 6002**

Advanced Computational Methods I

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# 1. Lecture 1

START OF WEEK 1

## 1.1. Hello World in C using Quincy

The code required to create an executable file which prints hello world to the console is shown in **Figure 1**.

```
1 #include <stdio.h>
2
3 int main()
4 {
5     printf("Hello World \n");
6     return 0;
7 }
```

Figure 1: C code which prints hello world to terminal

- **Line 1:** Imports the header file called the **standard input output library** which contains the **printf** function that is utilized later in the code. This line is ran before the code is compiled and pastes in all of the functions within the header file.
- **Line 3:** Defines the **main** function which is always where execution starts for a C program. The function is defined as an integer using **int** and returns 0 to the OS upon successful execution.
- **Line 5** Utilizes the **printf** function to print “hello world” to the terminal. This function requires **\n** at the end to start a new line and each line of a C program requires a semi-colon to signify the end of a line of code.

If this code is created as a C source file in Quincy it can be **saved** using **ctrl + s**, **compiled** using **F5** and than **executed** using **F9**. This will print the hello world text in the Quincy terminal as shown in **Figure 2**.

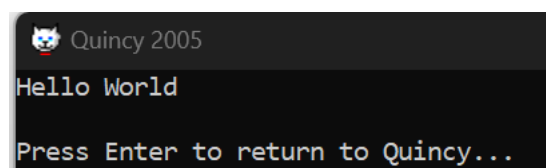


Figure 2: **Figure 1** executable file output

When pressing **F5** Quincy sends a command to the C compiler which contains the following key flags:

- **-ansi:** Ensures compatibility with C90 standard.
- **-Wall:** Enables all warnings.
- **-pedantic:** Issues all warnings ISO C requires (C90 when using -ansi).

## 1.2. Using the Command Line

The command line is a **non-graphical way of working with a computer, via screen and keyboard**. There exist many different terminals, some common window terminal commands are shown below:

- `dir` : Display all files in the current folder.
- `cd \` : Navigate to root folder.
- `cd \<dirname>` : Navigate to the specified folder.
- `cd ..` : Move up one folder.
- `mkdir <newdir>` : Make a new folder.
- `rmdir <rmdir>` : Remove a folder.
- `rename <old> <new>` : Rename a file or folder.
- `move <file1> <file2>` : Move file1 to file2.
- `del <file>` : Delete file.
- `cls` : Clear screen.
- `help` : Shows all commands.
- `copy <src> <dest>`: “Copy a file from src to dest.”,
- `type <file>`: “Print the contents of a file.”,
- `echo <text>`: “Print text to the console.”,
- `exit`: “Close the command prompt.”,
- `path`: “Show system PATH variable.”,
- `ipconfig`: “Display network configuration.”,
- `ping <host>`: “Send ICMP packets to a host.”,
- `tasklist`: “List running processes.”,
- `taskkill /IM <process> /F`: “Kill a running process.”,
- `systeminfo`: “Display detailed system information.”

## 2. Lecture 2

### 2.1. Command Line

It was previously states that a command line is a non-graphical way of interacting with the computer using the screen and a keyboard. The command line like many other programming languages is a **REPL** type of program, which stands for:

- **Read**: read user input.
- **Evaluate**: run the command.
- **Print**: show the output.
- **Loop**: wait for the next command.

The command line can be used to manually perform many OS tasks (moving, renaming, deleting files and folders etc.). Alternatively a bash file (**.bat**) can be used to chain together commands and automate scripts.

GUIs are not easy to program, often add unnecessary complexity to the program and are difficult to automate. The command line is therefore an attractive alternative for user interaction. The shell allows for interaction with the command line and also allows for many different programs to interact with one another. To allow for interactivity, Shell's use the **Unix philosophy** which states:

- Write programs that do one thing and do it well.
- Write programs to work together.
- Write programs to handle text streams (universal interface).

### 2.2. Input Output (I/O) Streams

The input and output of programs is done via a stream. There exists three standard streams for OSs which are shown in **Table 1**.

| Standard Stream | Abbreviation  | File Descriptor | Connected to |
|-----------------|---------------|-----------------|--------------|
| Input           | <b>stdin</b>  | 0               | Keyboard     |
| Output          | <b>stdout</b> | 1               | Screen       |
| Error           | <b>stderr</b> | 2               | Screen       |

Table 1: Standard streams

### 2.3. Program I/O in C

The built in C library **stdio** defines these streams. As well as some functions which make use of these streams, as shown below:

- **printf()** → Utilizes the **stdout** to print to the terminal.
- **fprintf()** → Takes an argument (either **stdout** or **stderr**) to either print out to standard out or standard error.
- **getchar()** → Get one character from **stdin** (note that this saves as the ASCII value of the character).
- **putchar()** → Send one character to **stdout** (note that this takes the ASCII number and outputs the corresponding character).

One common tool to stop an infinitely looping code is to use the **EOF** (end of file) character, which can be inputted in a windows shell by doing **ctrl + Z** and then pressing **Enter**.

Note that for **fprintf()** if **stdout** is passed then it behaves the same as **printf**. If **stderr** is instead passed than an **unbuffered, undirectable** output is printed to the shell.

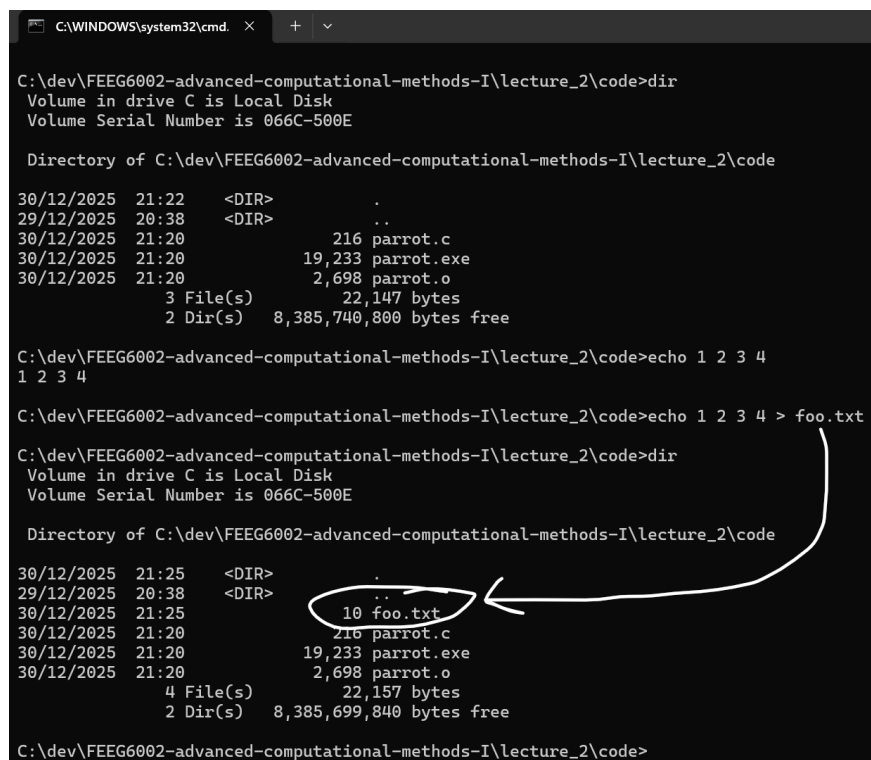
Applying these functions in one program, a parrot code can be created as shown in **Figure 3** which returns the inputted text from the terminal.

```
1  #include <stdio.h>
2  int main()
3  {
4      int c;
5      fprintf(stderr, "Enter some characters (Ctrl-D quits)\n");
6      while ((c = getchar()) != EOF) {
7          putchar(c);
8      }
9      fprintf(stderr, "Goodbye\n");
10     return 0;
11 }
```

Figure 3: C code which parrots the input and prints it back out to the terminal.

## 2.4. Program I/O in Terminal

The **echo** command can be used to print things within the terminal (**stdout**), the standard output can be redirected and written to a file using **>** this is shown in **Figure 4**



```
C:\WINDOWS\system32\cmd. x + v

C:\dev\FEEG6002-advanced-computational-methods-I\lecture_2\code>dir
Volume in drive C is Local Disk
Volume Serial Number is 066C-500E

Directory of C:\dev\FEEG6002-advanced-computational-methods-I\lecture_2\code

30/12/2025  21:22    <DIR>          .
29/12/2025  20:38    <DIR>          ..
30/12/2025  21:20                216 parrot.c
30/12/2025  21:20            19,233 parrot.exe
30/12/2025  21:20            2,698 parrot.o
               3 File(s)            22,147 bytes
               2 Dir(s)      8,385,740,800 bytes free

C:\dev\FEEG6002-advanced-computational-methods-I\lecture_2\code>echo 1 2 3 4
1 2 3 4

C:\dev\FEEG6002-advanced-computational-methods-I\lecture_2\code>echo 1 2 3 4 > foo.txt

C:\dev\FEEG6002-advanced-computational-methods-I\lecture_2\code>dir
Volume in drive C is Local Disk
Volume Serial Number is 066C-500E

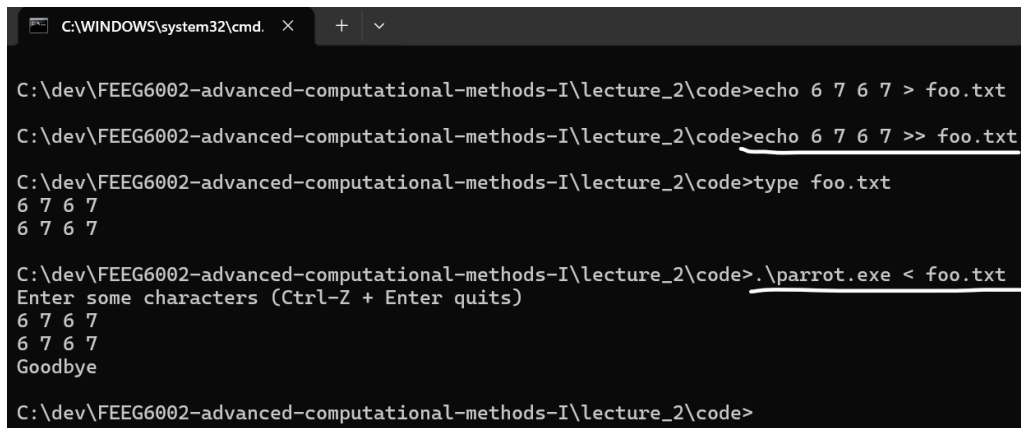
Directory of C:\dev\FEEG6002-advanced-computational-methods-I\lecture_2\code

30/12/2025  21:25    <DIR>          .
29/12/2025  20:38    <DIR>          ..
30/12/2025  21:25            10 foo.txt
30/12/2025  21:20                216 parrot.c
30/12/2025  21:20            19,233 parrot.exe
30/12/2025  21:20            2,698 parrot.o
               4 File(s)            22,157 bytes
               2 Dir(s)      8,385,699,840 bytes free

C:\dev\FEEG6002-advanced-computational-methods-I\lecture_2\code>
```

Figure 4: Redirecting terminal **stdout**.

To append to a text file `>>` can be used instead. The **stdin** can also be redirected using the `<` operator, this is shown in **Figure 5**.



```
C:\WINDOWS\system32\cmd. X + v

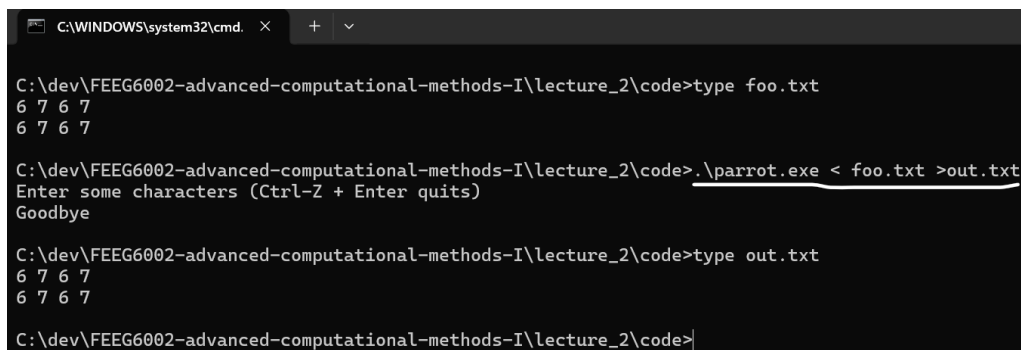
C:\dev\FEEG6002-advanced-computational-methods-I\lecture_2\code>echo 6 7 6 7 > foo.txt
C:\dev\FEEG6002-advanced-computational-methods-I\lecture_2\code>echo 6 7 6 7 >> foo.txt
C:\dev\FEEG6002-advanced-computational-methods-I\lecture_2\code>type foo.txt
6 7 6 7
6 7 6 7

C:\dev\FEEG6002-advanced-computational-methods-I\lecture_2\code>.\parrot.exe < foo.txt
Enter some characters (Ctrl-Z + Enter quits)
6 7 6 7
6 7 6 7
Goodbye

C:\dev\FEEG6002-advanced-computational-methods-I\lecture_2\code>
```

Figure 5: Redirecting terminal **stdin** into a executable file.

The output of the **parrot.exe** can itself be redirected into another text file by utilizing both the `>` command, as shown in **Figure 6**.



```
C:\WINDOWS\system32\cmd. X + v

C:\dev\FEEG6002-advanced-computational-methods-I\lecture_2\code>type foo.txt
6 7 6 7
6 7 6 7

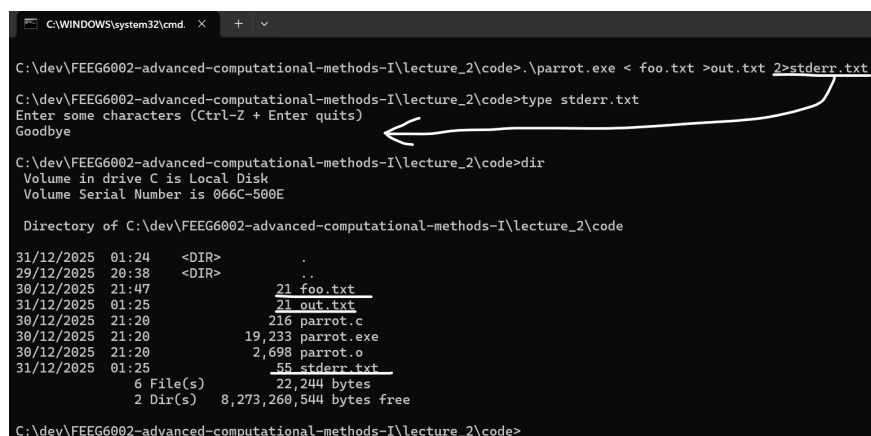
C:\dev\FEEG6002-advanced-computational-methods-I\lecture_2\code>.\parrot.exe < foo.txt >out.txt
Enter some characters (Ctrl-Z + Enter quits)
Goodbye

C:\dev\FEEG6002-advanced-computational-methods-I\lecture_2\code>type out.txt
6 7 6 7
6 7 6 7

C:\dev\FEEG6002-advanced-computational-methods-I\lecture_2\code>
```

Figure 6: Redirecting program **stdout** into a text file.

Note that the **stderr** from the program is still outputted to the shell, this can also be redirected using the `2` file descriptor, this is shown in **Figure 7**.



```
C:\WINDOWS\system32\cmd. X + v

C:\dev\FEEG6002-advanced-computational-methods-I\lecture_2\code>.\parrot.exe < foo.txt >out.txt 2>stderr.txt
C:\dev\FEEG6002-advanced-computational-methods-I\lecture_2\code>type stderr.txt
Enter some characters (Ctrl-Z + Enter quits)
Goodbye

C:\dev\FEEG6002-advanced-computational-methods-I\lecture_2\code>dir
Volume in drive C is Local Disk
Volume Serial Number is 066C-500E

Directory of C:\dev\FEEG6002-advanced-computational-methods-I\lecture_2\code

31/12/2025 01:24 <DIR> .
29/12/2025 20:38 <DIR> ..
30/12/2025 21:47      21 foo.txt
31/12/2025 01:25      21 out.txt
30/12/2025 21:20     216 parrot.c
30/12/2025 21:20    19,233 parrot.exe
30/12/2025 21:20    2,698 parrot.o
31/12/2025 01:25      55 stderr.txt
               6 File(s)      22,244 bytes
               2 Dir(s)      8,273,260,544 bytes free

C:\dev\FEEG6002-advanced-computational-methods-I\lecture_2\code>
```

Figure 7: Redirecting program **stdout** and **stderr** into a text file.

Note that if anything is ever re-routed to **dev\null** then this output is quietly destroyed. Pipes can be used to chain together commands, effectively chaining the **stdout** of one command to the **stdin** of the second command. An example of using pipes to chain together commands is shown in **Figure 8**.

```
C:\dev\FEEG6002-advanced-computational-methods-I\lecture_2\code>dir
Volume in drive C is Local Disk
Volume Serial Number is 066C-500E

Directory of C:\dev\FEEG6002-advanced-computational-methods-I\lecture_2\code

31/12/2025  01:24    <DIR>          .
29/12/2025  20:38    <DIR>          ..
30/12/2025  21:47             21 foo.txt
31/12/2025  01:25             21 out.txt
30/12/2025  21:20            216 parrot.c
30/12/2025  21:20          19,233 parrot.exe
30/12/2025  21:20          2,698 parrot.o
31/12/2025  01:25             55 stderr.txt
               6 File(s)        22,244 bytes
               2 Dir(s)      8,079,667,200 bytes free

C:\dev\FEEG6002-advanced-computational-methods-I\lecture_2\code>del foo.txt | del out.txt | del stderr.txt

C:\dev\FEEG6002-advanced-computational-methods-I\lecture_2\code>dir
Volume in drive C is Local Disk
Volume Serial Number is 066C-500E

Directory of C:\dev\FEEG6002-advanced-computational-methods-I\lecture_2\code

31/12/2025  01:34    <DIR>          .
29/12/2025  20:38    <DIR>          ..
30/12/2025  21:20             216 parrot.c
30/12/2025  21:20          19,233 parrot.exe
30/12/2025  21:20          2,698 parrot.o
               3 File(s)        22,147 bytes
               2 Dir(s)      8,079,659,008 bytes free

C:\dev\FEEG6002-advanced-computational-methods-I\lecture_2\code>
```

Figure 8: Utilizing pipes in the terminal to chain commands.



### 3. Lecture 3

START OF WEEK 2

### 4. Lecture 4

#### 4.1. Basic Data Types

There exists 4 key datatypes within C, these are:

- **int** → Integer or a whole number. Uses 4 bytes (32 bits) of memory with 1 sign bit and 31 magnitude bits. Can store numbers in the range of  $-2,147,483,648$  to  $+2,147,483,647$
- **char** → Stores a single character using 1 byte (4 bits). Stores the character as an ASCII code in memory.
- **float** → Stores a decimal number in 4 bytes (32 bits). Called single precision, this allows for 6 - 7 decimal digits and has a range from  $1.175 \times 10^{-38}$  to  $3.402 \times 10^{38}$ .
- **double** → Stores a decimal number in 8 bytes (64 bits). Called double precision, this allows for 15 - 16 decimal digits and has a range from  $2.225 \times 10^{-308}$  to  $1.798 \times 10^{308}$ .
- **bool** → Can be True or False (1 or 0).

#### 4.2. Signed, Unsigned, Short and Long Datatypes

**int** and **char** datatypes can be signed or unsigned, by default they are both signed. Declaring an integer as unsigned means it can **only store non-negative values**. This means instead of the range being centered at zero, all bits are used to store the number. For a 32 bit integer, this means the range for this variable is 0 to 4,294,967,295.

An integer can also be defined as **short**, **long** and **long long**, which specify how many bits are used to store the number. The number of bits for each type as well as their maximum ranges are shown in **Table 2**.

| Keyword   | Windows Size | Linux/macOS Size | Signed     | Unsigned Range |
|-----------|--------------|------------------|------------|----------------|
| short     | 16-bit       | 16-bit           | $\pm 32k$  | 0 - 65k        |
| int       | 32-bit       | 32-bit           | $\pm 2.1B$ | 0 - 4.2B       |
| long      | 32-bit       | 64-bit           | varies     | varies         |
| long long | 64-bit       | 64-bit           | $\pm 9e18$ | 0 - 1.8e19     |

Table 2: Integer type sizes and ranges

#### 4.3. Using printf to Print Variables

The **printf** command can be used to print out all of the variable types previously mentioned. On top of this, formatting can also be used to print specific outputs. An example code which shows this is shown in **Figure 9**.

|  |   |
|--|---|
| <pre> 1  #include &lt;stdio.h&gt; 2 3  int main(void) { 4      int var1 = -42; 5      unsigned int var2 = 142; 6      float var3 = 3.14; 7      double var4 = 3.1428; 8      char var5[] = "Hello World"; 9 10     printf("Printing int var1=%d\n", var1); 11     printf("Printing unsigned int var2=%u\n", var2); 12     printf("Printing float var3=%f\n", var3); 13     printf("Printing double var4=%f\n", var4); 14     printf("Printing double in scientific notation 15     var4=%e\n", var4); 16     printf("Printing char[] var5=%s\n", var5); 17     return 0; 18 } </pre> | <div style="text-align: right; border: 1px solid #ccc; padding: 2px; margin-bottom: 5px;">C Shell</div> <pre> 1  C:\&gt;. 2  \printing_data_types.c 3  Printing int var1=-42 4  Printing unsigned int 5  var2=142 6  Printing float 7  var3=3.140000 8  Printing double 9  var4=3.142800 10 Printing double in 11 scientific notation 12 var4=3.142800e+000 13 Printing char[] 14 var5=Hello World </pre> |
|--|---|

Figure 9: C code which assigns each variable type and prints it.

Further formatting can be achieved by using specific formatters, this is shown in **Figure 10**.

|   |  |
|---|--|
| <pre> 1  #include &lt;stdio.h&gt; 2 3  int main(void) { 4 5      double pi = 3.1415926535897931; 6 7      printf("As a standard float representation: 8      pi=%f\n", pi); 9      printf("In exponential notation: pi=%e\n", pi); 10     printf("Whichever of the above two is shorter: 11     pi=%g\n", pi); 12     printf("Request 10 digits overall: pi=%10f\n", pi); 13     printf("With 3 postdecimal digits: pi=%10.3f\n", 14     pi); 15     printf("12 postdecimal digits: pi=%.12f\n", pi); 16 17     return 0; 18 } </pre> | <div style="text-align: right; border: 1px solid #ccc; padding: 2px; margin-bottom: 5px;">C Shell</div> <pre> 1  C:\&gt;. 2  \printing_data_types.c 3  As a standard float 4  representation: 5  pi=3.141593 6  In exponential 7  notation: 8  pi=3.141593e+000 9  Whichever of the 10 above two is shorter: 11 pi=3.14159 12 Request 10 digits 13 overall: pi= 14 3.141593 15 With 3 postdecimal 16 digits: pi=      3.142 17 12 postdecimal 18 digits: 19 pi=3.141592653590 </pre> |
|---|--|

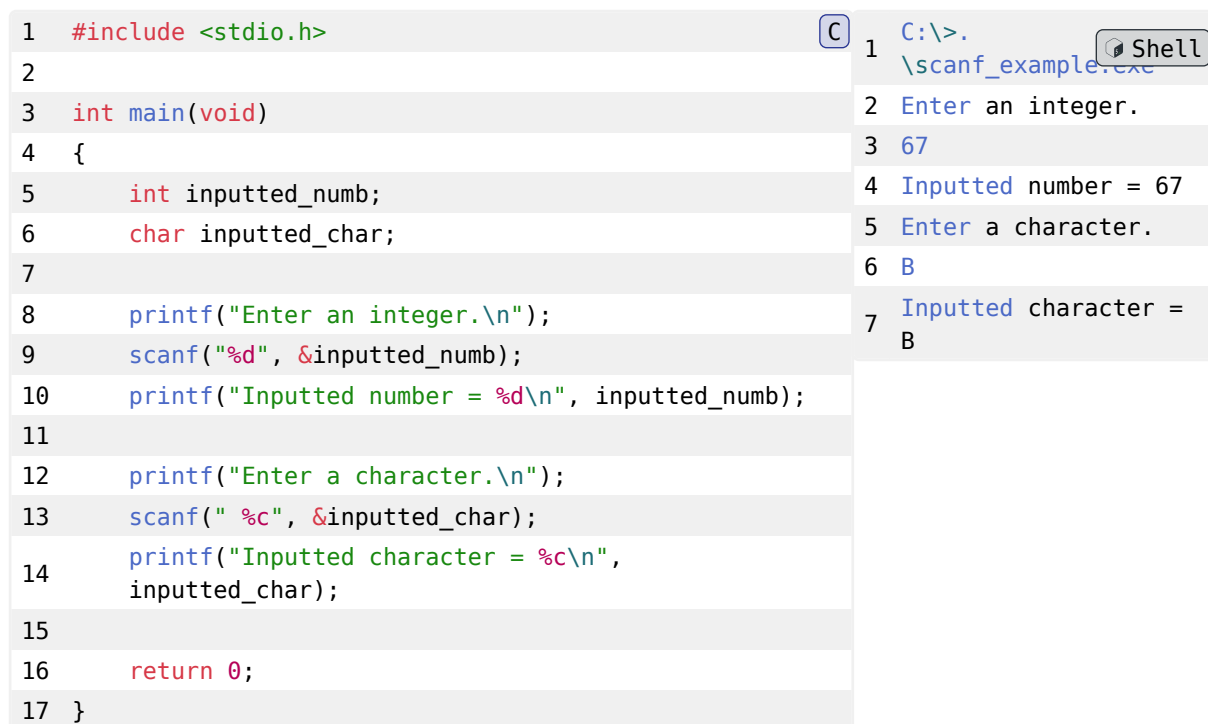
Figure 10: C code which customizes the output of **printf** using formatting flags.

A summary of which formatters are used with specific datatype is shown below:

- `%d` & `%i` → Signed **int**, **short**, **chars**.
- `%ld` & `%li` → Signed **long** integers.
- `%f` → Floating point representation of **double** or **float**.
- `%e` → Exponential notation of **double** or **float**.
- `%g` → **f** or **e** depending on which is shorter.
- `%s` → Arrays of characters (**char**, **char[]**).
- `%u` → Unsigned integers (unsigned **int**, **short**, **char**).
- `%.<n1>.<n2>f` → **n1** overall digits and **n2** decimal digits (This can result in whitespace).

#### 4.4. Using `scanf`

The `scanf` command is useful for allowing the user to input a value which can then be saved as a variable, an example program which takes a character and integer input is shown in **Figure 11**.

The image shows a code editor with a C program on the left and its execution output in a terminal window on the right. The C program defines two variables, 'inputted\_num' and 'inputted\_char', and uses printf to prompt the user for an integer and a character. It then uses scanf to read the input. The terminal window shows the program being run from the C:\> directory, with the user entering '67' for the integer and 'B' for the character. The program's output shows 'Inputted number = 67' and 'Inputted character = B'.

```
1  #include <stdio.h>
2
3  int main(void)
4  {
5      int inputted_num;
6      char inputted_char;
7
8      printf("Enter an integer.\n");
9      scanf("%d", &inputted_num);
10     printf("Inputted number = %d\n", inputted_num);
11
12     printf("Enter a character.\n");
13     scanf(" %c", &inputted_char);
14     printf("Inputted character = %c\n",
15           inputted_char);
16
17     return 0;
18 }
```

Terminal Output:

```
C:\>. \scanf_example.exe
Enter an integer.
67
Inputted number = 67
Enter a character.
B
Inputted character = B
```

Figure 11: C code which uses `scanf` to take in a user input.

Note that for this code to run a space is required in line 13 before `%c` as the `\n` from the previous line effects it. Furthermore, the `&` refers to the memory address of the variable, not its value.

#### 4.5. Conditional Statements in C

**if-else** and **if-else if-else** statements can be used to run a specific block of code when a condition is met. There are two types of conditions that can be specified within a conditional, these are **relational operators** and **logical operators**. These can be combined together to form composite statements, all of these operators are shown below:

- **Relational operators:**
- **a==b** → a equal to b
- **a!=b** → a not equal to b
- **a>b** → a greater than b
- **a<b** → a less than b
- **a>=b** → a greater than or equal to b
- **a<=b** → a less than or equal to b
- **Logical operators:**
- **&&** → logical AND
- **||** → logical OR
- **!** → logical NOT

An example code that uses composite statements using multiple operators is shown in **Figure 12**.

|   |   |
|---|---|
| <pre>1  #include &lt;stdio.h&gt; 2 3  int main(void) 4  { 5      int user_input; 6 7      printf("Enter an integer.\n"); 8      scanf(" %d", &amp;user_input); 9 10     if (user_input &gt; -10 &amp;&amp; user_input &lt; 0) { 11         printf("Input is between -10 and 0\n"); 12     } else if (user_input == 5) { 13         printf("Input is 5\n"); 14     } else { 15         printf("The input is: %d\n", 16             user_input); 17     } 18     return 0; 19 }</pre> | <div style="border: 1px solid #ccc; padding: 5px;"><div style="display: flex; justify-content: space-between; align-items: center;"><span>C</span><span>Shell</span></div><pre>1  C:\&gt;.    \conditional_statements.exe 2  Enter an integer. 3  5 4  Input is 5 5  C:\&gt;.    \conditional_statements.exe 6  Enter an integer. 7  -7 8  Input is between -10 and 0 9  C:\&gt;.    \conditional_statements.exe 10 Enter an integer. 11 52 12 The input is: 52</pre></div> |
|---|---|

Figure 12: C code which uses conditional statements.

