Streams

```
Module Code: ELEE1147

Module Name: Programming for Engineers

Credits: 15

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```

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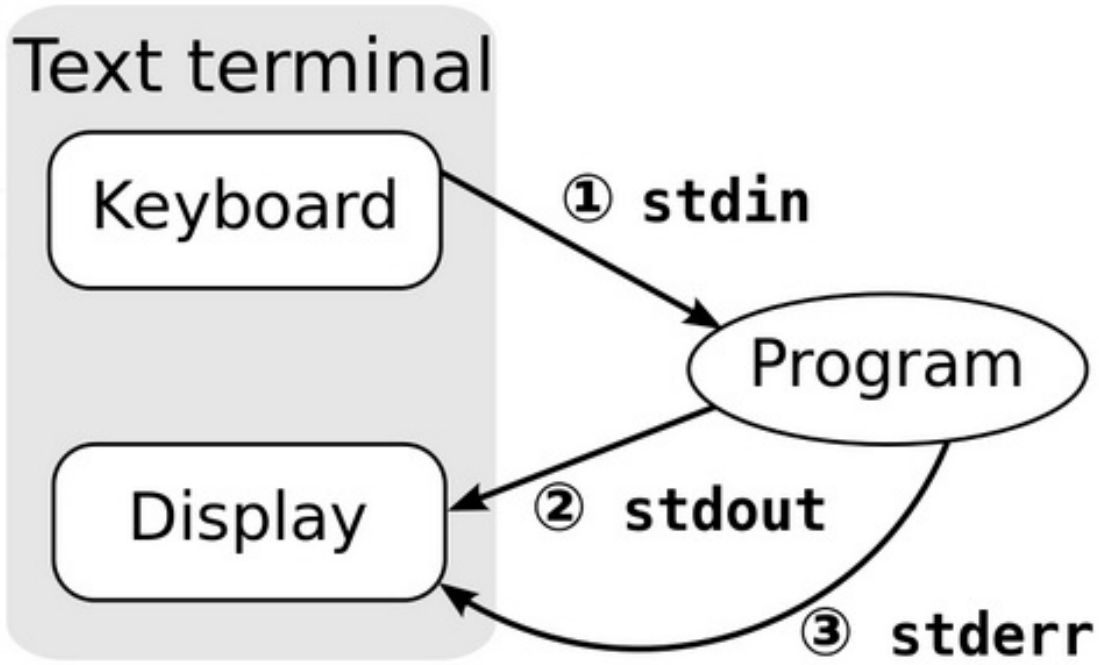
Introduction to Streams

- Streams are sequences of data elements.
- In C, we commonly work with three standard streams:
  - Standard Input (**stdin**)
  - Standard Output (**stdout**)
  - Standard Error (**stderr**)



Kernel

When using streams, we need to remember that all of this is handled by the kernel.

System calls, such as `open()`, `write()` and `exit()` can be invoked by user and system level program:

- `open()`: It is the system call to open a file.
- `read()`: This system call opens the file in reading mode. Multiple processes can execute the `read()` system call on the same file simultaneously.
- `write()`: This system call opens the file in writing mode. Multiple processes can not execute the `write()` system call on the same file simultaneously.
- `close()`: This system call closes the opened file.

But what about concurrent `write()`

OneDrive and GoogleDrive etc implement mechanisms to allow concurrent access while avoiding conflicts when multiple processes or users attempt to write to the same file:

- **Granular Locking Mechanism**, portion of the file is locked
- **Conflict Detection and Resolution**, versioning and merging
- **Real-Time Collaboration**, syncing changes at the character or paragraph level. Changes are merged in real time, allowing multiple users to work on a file simultaneously.
- **Metadata, State & Periodic syncing, and local caching**, managed by using timestamping, version numbers and checksums/hashes

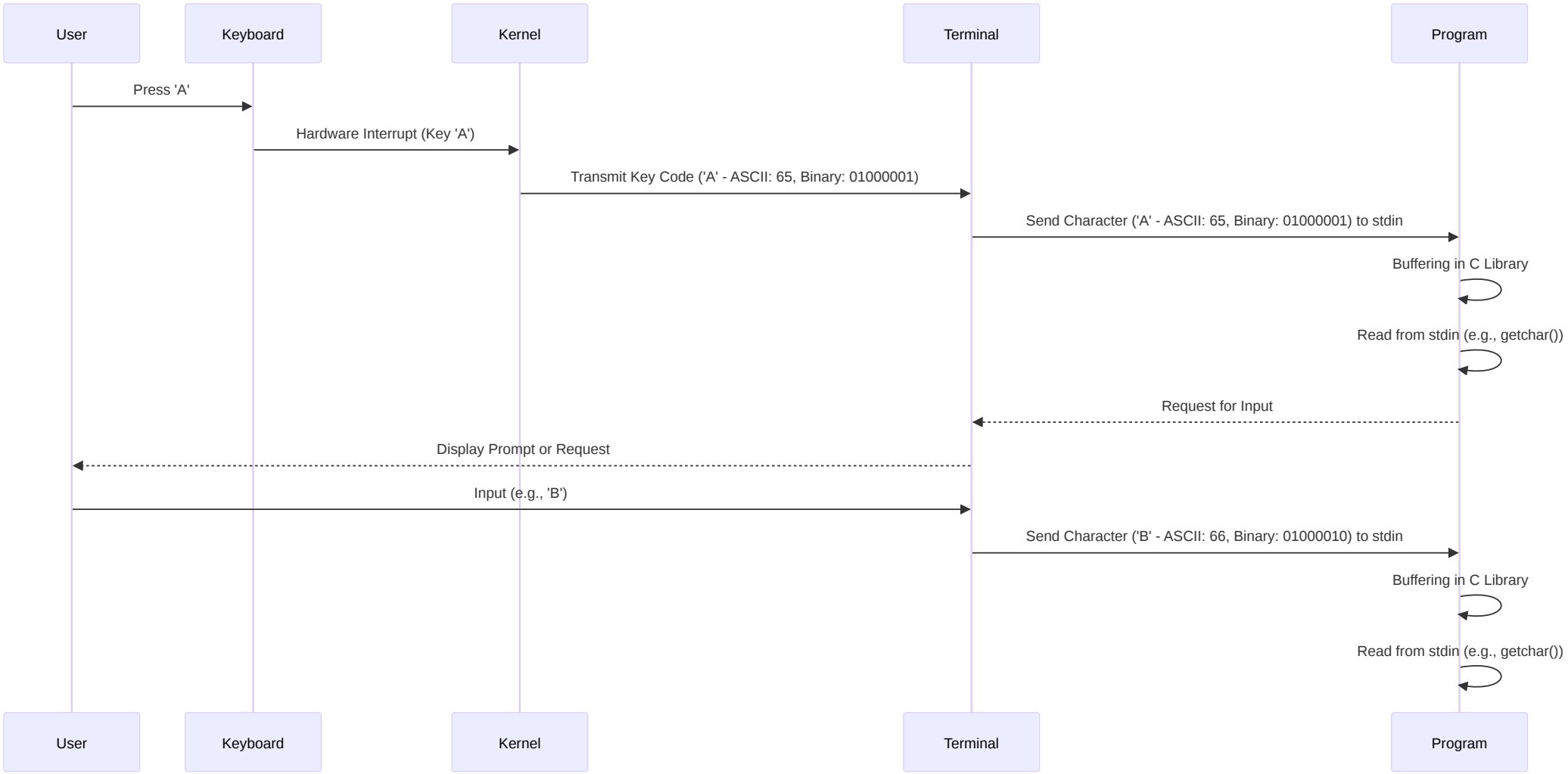
Standard Input (stdin)

- **stdin** is the **st**andar**d in**put stream.
- It is used to read input from the user or from another program.
- Functions like `scanf()` / `scanf_s` and `getchar()` read from stdin.

```c
int num;
printf("Enter a number: ");
scanf_s("%d", &num);
```

- `scanf_s()` reads input from the standard input (usually the keyboard) and stores it in the specified variable.
- In this example, it waits for the user to input an integer and stores it in the variable `num`.

Standard Input flow:



Standard Output (stdout)

- **stdout** is the **st**andar**d out**put stream.
- It is used to display output to the user or another program.
- Functions like `printf()` and `putchar()` write to stdout.

```c
int result = 42;
printf("The answer is: %d\n", result);
```

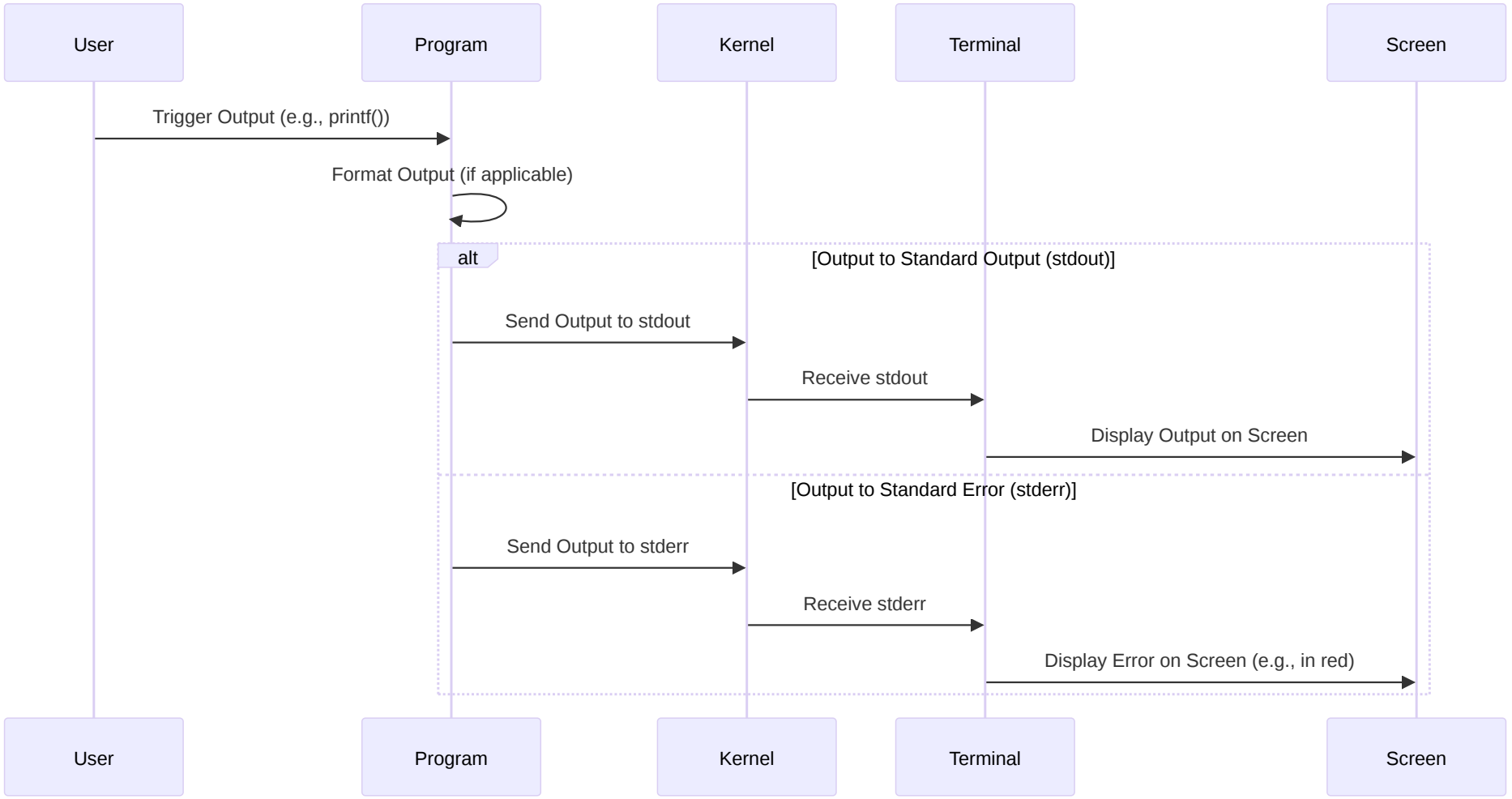
Standard Error (stderr)

- **stderr** is the **st**andar**d err**or stream.
- It is used to display error messages or diagnostic information.
- It's particularly useful to separate error messages from regular output.

```c
FILE *file = fopen("nonexistent.txt", "r");
if (file == NULL) {
    fprintf(stderr, "Error: Unable to open the file!\n");
}
```

> Note:
>
> > `printf` uses stdout
> >
> > `fprintf` can use different streams

Standard Ouput and Error flow:



Stream Functions in C

C provides functions to interact with streams in the <stdio.h> header, like these for handling files:

- `fopen()`: Opens a file stream.
- `fclose()`: Closes a file stream.
- `fprintf()`: Writes to a stream with formatting.
- `fscanf()`: Reads from a stream with formatting.

File Operations in C: Open, Read, Write, Execute

In C programming, file operations are crucial for interacting with files on a computer system. The primary operations include:

- opening files for:
  - reading from them,
  - writing to them,
- and executing them.

Opening a File

To operate on a file, you must first open it using the `fopen` function. This function allows you to specify the file's path, mode (read, write, execute), and returns a file pointer for further operations.

Example:

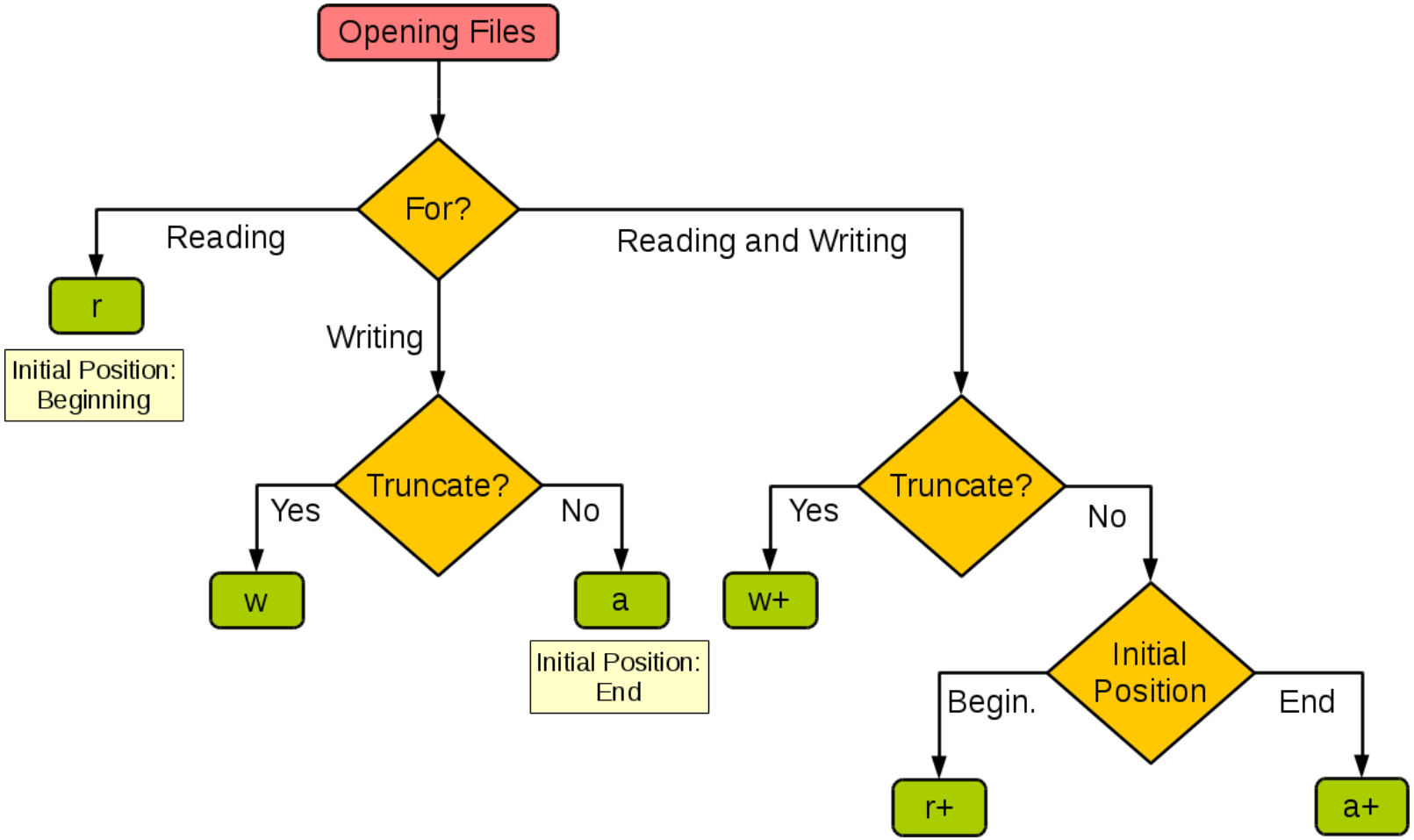
```
FILE *filePtr = fopen("example.txt", "r"); // Open for reading
```

File Modes

- **Read (`"r"`) Mode**: Open a file for reading. The file must exist.
- **Write (`"w"`) Mode**: Open a file for writing. If the file exists, its content is truncated; if not, a new file is created.
- **Append (`"a"`) Mode**: Open a file for writing, but append data to the end. If the file doesn't exist, it is created.

> **Note:**
>
> > Linux file modes, `r`, `w`, `x`, whereas here there is no execute.

File Mode FLow



File Modes

	`r`	`r+`	`w`	`w+`	`a`	`a+`
read - reading from file is allowed	+	+		+		+
write - writing to file is allowed		+	+	+	+	+
write after seek	+	+	+			
create - file is created if it does not exist yet			+	+	+	+
truncate - during opening of the file it is made empty (all content of the file is erased)		+	+			
position at end - after file is opened, initial position is set to the end of the file					+	+

Write and Read

```
// Write Mode
FILE *writeFile = fopen("example.txt", "w");
fprintf(writeFile, "Hello, World!");
fclose(writeFile);

// Append Mode
FILE *appendFile = fopen("example.txt", "a");
fprintf(appendFile, "\nAppended Content");
fclose(appendFile);
```

Single Write Instance

Only one instance of a file can be opened for writing at a time. This prevents multiple processes from simultaneously modifying the same file, avoiding data corruption.

Example:

```
FILE *writeFile1 = fopen("example.txt", "w");

// Error: Cannot open for write concurrently
FILE *writeFile2 = fopen("example.txt", "w");
```

Dirty Files

When a file is opened for writing, it becomes a "dirty" file. This means changes are made in memory but not yet saved to disk. To persist changes, use the `fclose()` function.

Example:

```
FILE *dirtyFile = fopen("example.txt", "w"); // file is open for writing too
fprintf(dirtyFile, "Hello, World!"); // File is dirty
fclose(dirtyFile); // Save changes to disk, file is "clean"
```

Why Close Files?

When working with files in C, it's crucial to close them properly after operations. Failing to do so can lead to unexpected behavior, data corruption, and resource leaks.

1. **Data Persistence:** Closing a file ensures that any changes made during read or write operations are saved to the underlying storage. Without proper closure, changes may be lost.
2. **Resource Management:** File operations involve system resources. Closing a file releases these resources, preventing potential memory leaks or system resource exhaustion.
3. **Avoiding Data Corruption:** Closing files properly helps avoid data corruption, especially when multiple programs or processes access the same file. It ensures exclusive access when needed.

Proper File Closure Example

```c
#include <stdio.h>

int main() {
    FILE *filePtr = fopen("example.txt", "w");

    if (filePtr != NULL) {
        fprintf(filePtr, "Hello, World!");
        fclose(filePtr); // Properly close the file
    } else {
        printf("Error opening the file!\n");
    }

    return 0;
}
```

Python

Same concepts, ever so slightly different syntax:

Reading:

```
file = open("example.txt", "r") # Open file for reading
content = file.read()  # Read entire file
line = file.readline()  # Read single line
lines = file.readlines()  # Read all lines into a list
```

Writing

```
file = open("example.txt", "w")  # Open file for writing
file.write("Hello, World!")  # Write a string to the file
```

Remember to close

```
file.close()  # Close the file
```