Software Testing

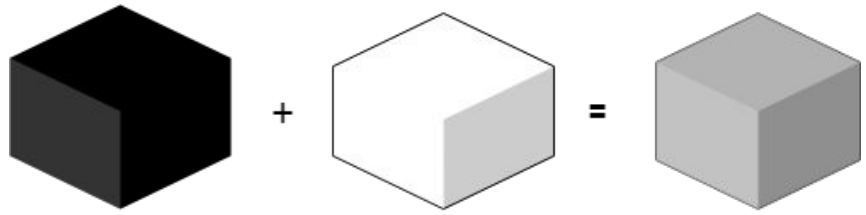
Programming and Development of Embedded Systems

Software Testing

- What is Software Testing?
  - The process to evaluate functionalities of a software in order to
    - Find whether the developed software fulfils the specified requirements or not
    - Identify the defects to ensure that the software is defect free
- Why is Software Testing Important?
  - Cost effectiveness
    - Identifying and fixing a bug early cost much less to fix it later
    - Nissan recalled 1.23 million cars in order to fix a problem with the backup cameras (2019)
  - Customer Satisfaction
    - Customer satisfaction is the ultimate goal of any business
    - Software testing improves the user experience of an application

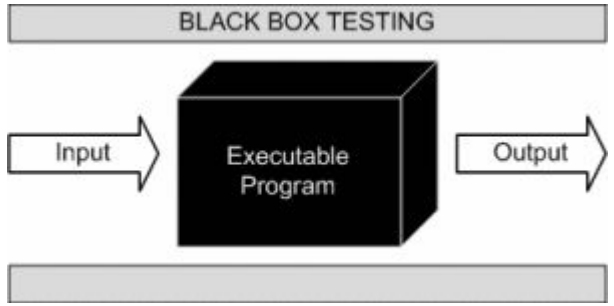
Software Testing

- Why is Software Testing Important?
  - Safety and Security
    - Testing helps in removing vulnerabilities in the product
    - China Airlines Airbus A300 crashed due to a software bug, killing 264 lives (1994)
  - Product Quality
    - Testing helps to deliver high quality products to clients according to requirements
- Testing Methods:
  - White Box Testing
  - Black Box Testing
  - Grey Box Testing
    - It is a combination of white-box testing and black-box testing
    - It is primarily used in Integration Testing



Black Box Testing

- It is also known as **Behavioral** testing
- The internal structure/design/implementation of the component/system is unknown
- The higher the level, bigger and more complex the box, the more black-box testing is used
- It can be used in the functional and non-functional testings
- Some Techniques:
  - Boundary Value Analysis
    - Involves the determination of boundaries for input values
    - Using values that are at the boundaries and just inside/outside of the boundaries as test data
  - Equivalence Partitioning
    - Dividing input values into valid and invalid partitions and using them as the test data
  - Cause-Effect Graphing:
    - Involves identifying the cases that produce a **Cause-Effect Graph**, and generating test cases



Black Box Testing

- Black Box Testing can be used to find errors in
  - Incorrect or missing functions, Interface errors and errors in data structures or external database
  - Behavior or performance errors, and initialization and termination errors
- Black Box Testing Advantages
  - Tests are done from a user's point of view
  - Tests can be done by a body independent of developers
  - Tester does not need to know programming languages or how the software has been implemented
  - Test cases can be designed as soon as the specifications are complete
- Black Box Testing Disadvantages
  - Only a small number of possible inputs can be tested and many program paths will be left untested
  - Without clear specifications, which is the case in many projects, test cases will be difficult to design
  - Tests can be redundant if the software designer/developer has already run a test case

What is Black Box Testing?

White Box Testing

- The internal structure/design/implementation of the component/system is known
- Testing is based on an analysis of the internal structure of the component or system
- White Box Testing Advantages
  - Testing is more complete, with the possibility of covering most paths
  - Code optimization by finding hidden errors
  - Testing can be started at an earlier stage
  - Test cases can be easily automated

- White Box Testing Disadvantages
  - It can be quite complex and expensive (highly skilled resources are required)
  - Test script maintenance can be a burden if the implementation changes too frequently
  - Since it is closely tied to the application under test, tools for every kind of implementation/platform may not be available

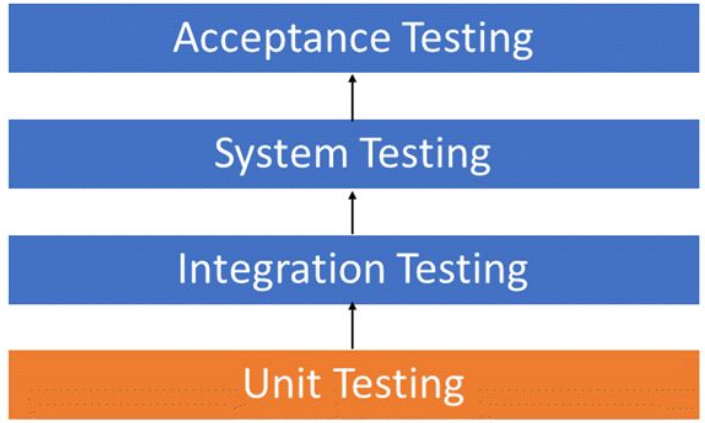
White Box Testing

- White Box Testing Techniques
  - Statement Coverage: Every possible statement in the code should be tested at least once during the testing
  - Branch Coverage: It checks every possible path (if-else and other conditional loops) of a software
- What do you verify in White Box Testing?
  - Internal security holes
  - The flow of specific inputs through the code
  - Expected output
  - The functionality of conditional loops
  - Testing of each statement, object, and function on an individual basis
  - Broken or poorly structured paths in the coding processes

What is White Box Testing? Tutorial with Examples

Testing Levels

- Software Testing Levels
  - Unit Testing
  - Integration Testing
  - System Testing
  - Acceptance Testing

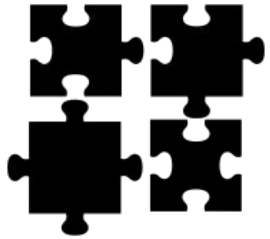


- Types of Software Testing
  - Functional Testing
  - Non-Functional Testing
  - Maintenance (Regression and Maintenance)
  - And etc.

Types of Software Testing: 100 Examples of Different Testing Types

Unit Testing

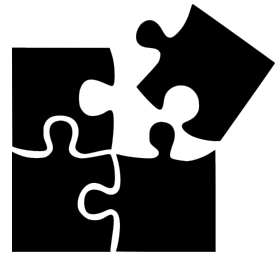
- The first level of testing; Individual units/components of a software are tested
- The purpose is to validate that each unit of the software performs as designed
- A unit is the smallest testable part of a software (e.g. functions, components and etc.)
- It is performed using the ***White Box Testing*** method
- It is normally performed by software developers themselves
- Unit Testing Benefits [What is Unit Testing? - Software Testing Tutorial]



  - It increases confidence in changing/maintaining code (they are run every time any code is changed)
  - Codes are more reusable. In order to make unit testing possible, codes need to be modular.
  - Development is faster (short term and long term)
    - Writing tests takes lesser time than the time it takes to run the tests
    - It takes lesser time to find and fix bugs during unit testing than system or acceptance testing
  - Debugging is easy. When a test fails, only the latest changes need to be debugged

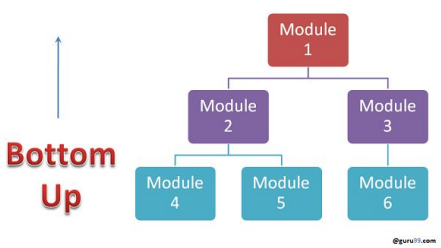
Integration Testing

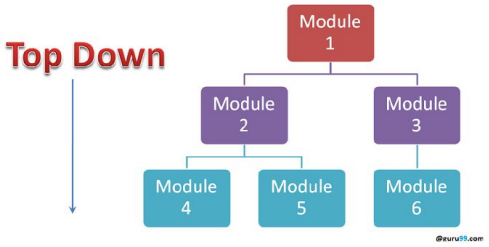
- It is a level of software testing where individual units are combined and tested as a group
- The purpose of this level of testing is to expose faults in the interaction between integrated units.
- Any of Black Box, White Box and Gray Box Testing methods can be used
- It is done by developers themselves or independent testers
- Integration Testing Approaches

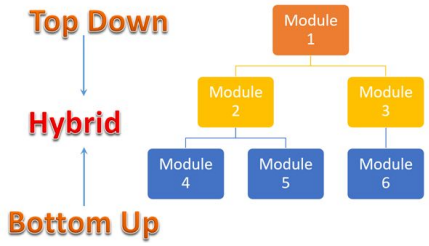


What is Integration Testing?

  - **Big Bang**: Here all components are integrated together at once and then tested
  - **Incremental**: Testing is done by joining two or more modules that are logically related
    - Bottom-up Integration, Top-down Integration and Hybrid/ Sandwich Integration

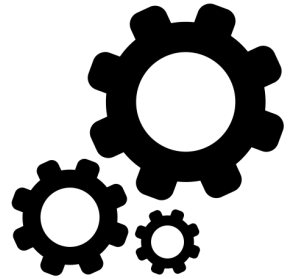






System Testing

- The process of testing a fully integrated system to verify that it meets specified requirements
- Usually, Black Box Testing method is used
- Independent testers perform System Testing
- Some Types of System Testing
  - Usability Testing: mainly focuses on the user's ease to use the application
  - Load Testing: is necessary to know that the product will work under real-life loads
  - Regression Testing: ensures that changes to the software have not caused new defect
  - Functional Testing: involves trying to find any possible missing functional requirements
  - Hardware/Software Testing: focuses on the interactions between the hardware and software during system testing
  - And etc.



What is System Testing? Software Testing Tutorial

Acceptance Testing

- Formal testing with respect to user needs, requirements, and business processes to:
  - Determine whether or not a system satisfies the acceptance criteria of the customer
  - Enable the customer or other authorized entities to determine whether or not to accept the system
- Usually, Black Box Testing is used in Acceptance Testing
- Who performs the Acceptance Testing?
  - Internal Acceptance Testing
    - Is performed by members of the organization who are not directly involved in the project
  - External Acceptance Testing: Is performed by people who are not employees of the organization
    - User Acceptance Testing: is performed by the end users of the software
      - They can be customers themselves or the customers' customers
    - Customer Acceptance Testing
      - Is performed by the customer of the organization that developed the software

1
- Developers have included features on their "own" understanding

2
- Requirements changes "not communicated" effectively to the developers

Test-Driven Development - TDD

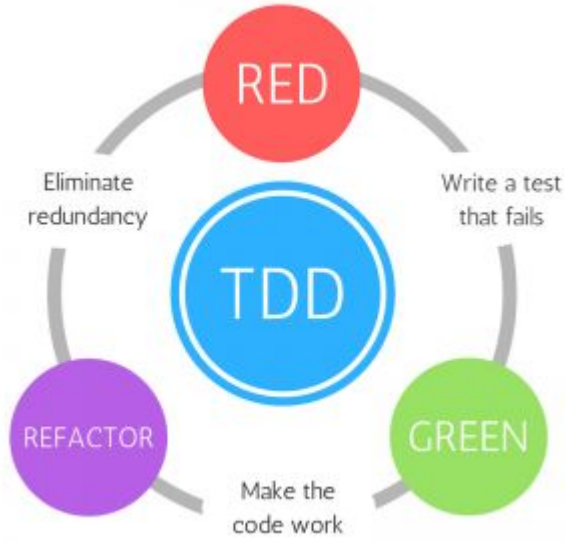
- Test-Driven Development is a technique for building software incrementally
  - Small steps can help form better components
- New automated unit test is followed immediately by production code satisfying the test
  - Healthy code growth, components are less prone of bugs
- Passing tests means the software is doing its job
  - Peace of mind, if you trust the tests you can have confidence in the code
  - Fewer bugs, ensuring components are well tested can help reduce bugs
- Failing tests means the software is not done
- Well tested code helps the software quality, maintainability and reliability
- Refactor friendly, tests ensure behaviour stays the same

Test-Driven Development - TDD

- Refactoring should make components easier to understand
  - Cleaner and more readable code
- Test automation is key to TDD
  - Testing is automatically performed by machine over and over.
  - No need for manual testing.
- TDD improves the functional and structural quality of the code
- Three rules of TDD
  - Write production code only to pass a failing unit test.
  - Write no more of a unit test than sufficient to fail.
    - Compilation failures are failures
  - Write no more production code than necessary to pass the one failing unit test.

Test-Driven Development - TDD

- The steps of the TDD cycle
  - Add a small test
  - Run all the tests and see the new one fails, maybe not even compile
  - Make the small changes needed to pass the failing test
  - Run all the tests and see the new one passes
  - Refactor to remove duplication and improve expressiveness
- Unit tests
  - Isolated, test cases should be kept to one component at a time
  - Small, expected behaviour should be broken down into minimal tests
  - Fast, it should be quick and easy to run your unit tests
  - Everywhere, local developer machine or remote building environment



Test-Driven Development - TDD

- General testing guidelines
  - Tests should
    - Be easy to follow
    - Help to maintain healthiness of the code
    - Tell us when something is changed
    - Be derived from requirements
    - Enforce a specific behaviour
    - Encourage refactoring
  - Different test cases require different test types
    - Evaluate the best test type for your tests
    - Tests can derive into multiple test types

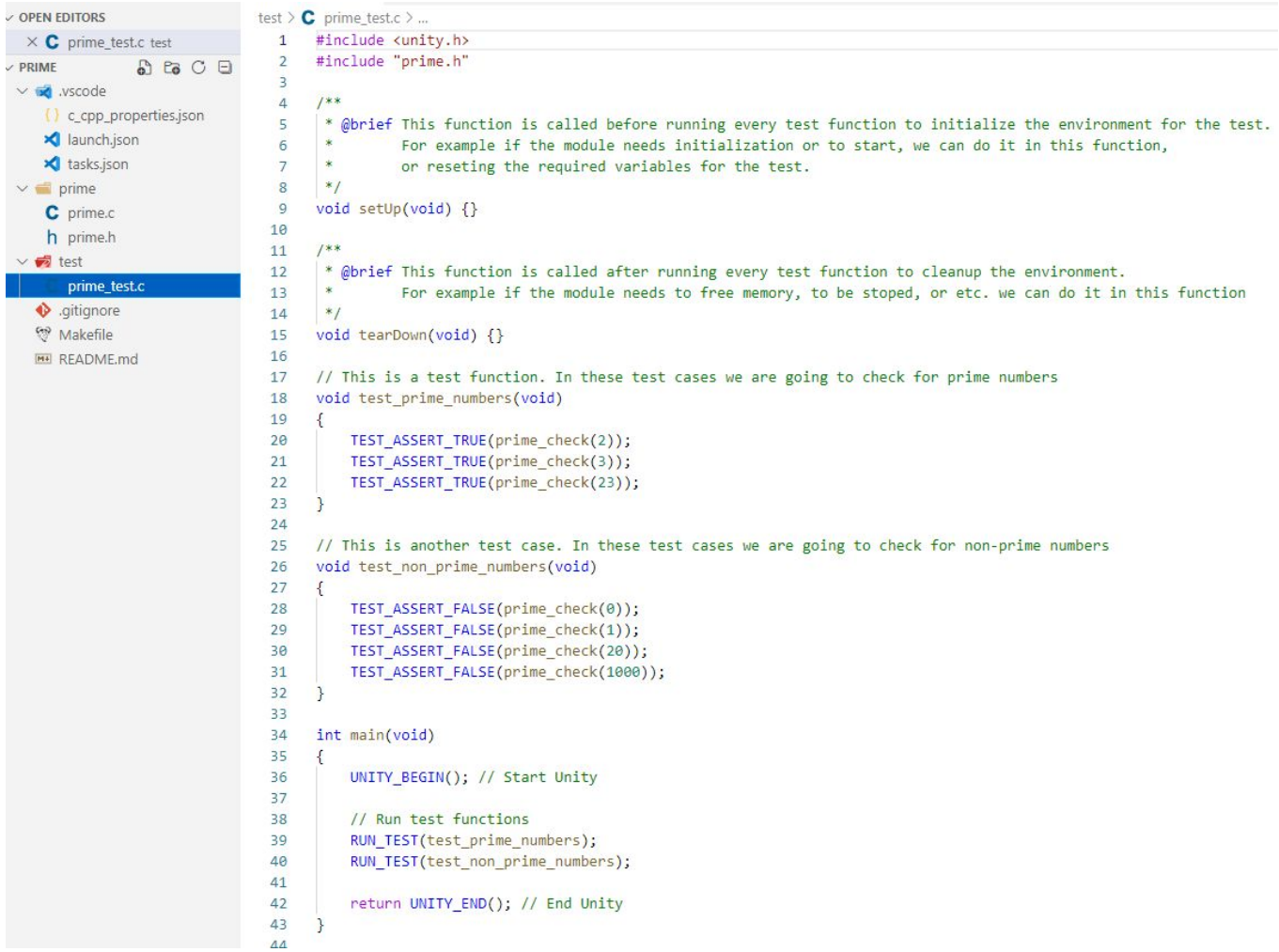
Test-Driven Development - TDD

- TDD Benefits
  - Fewer bugs: Small and large logic errors are found quickly during development
  - Less debug time: Having fewer bugs means less debug time.
  - Fewer side effect defects: When new code violates a constraint or assumption, the tests scream
  - Documentation
    - Well-structured tests become a form of executable documentation
  - Improved design
    - A good design is a testable design.
    - You get an early warning of design problems if tests cannot be written for the code change
  - Progress monitor
    - The tests keep track of exactly what is working and how much work is done

Unity

- Unity is a portable unit testing framework written in standard C and supports testing of embedded systems. Unity Test
- Unity uses assertions to test the actual values and the expectations
- Assertions are statements of what we expect to be true about the code under test.
  - E.g. TEST_ASSERT_EQUAL_UINT8(expected, actual);
    - Checks if the expected value and the actual value are equal or not
    - If they are not equal, it means the test is failed
- Unity is used to test modules. Means that the code under test shall be module(s).
  - A module is a source(.c) and a header(.h) file.
  - To test a module you also need to create a test file (.c) and include unity.h
    - The test cases are implemented in this file.

Unity - Example



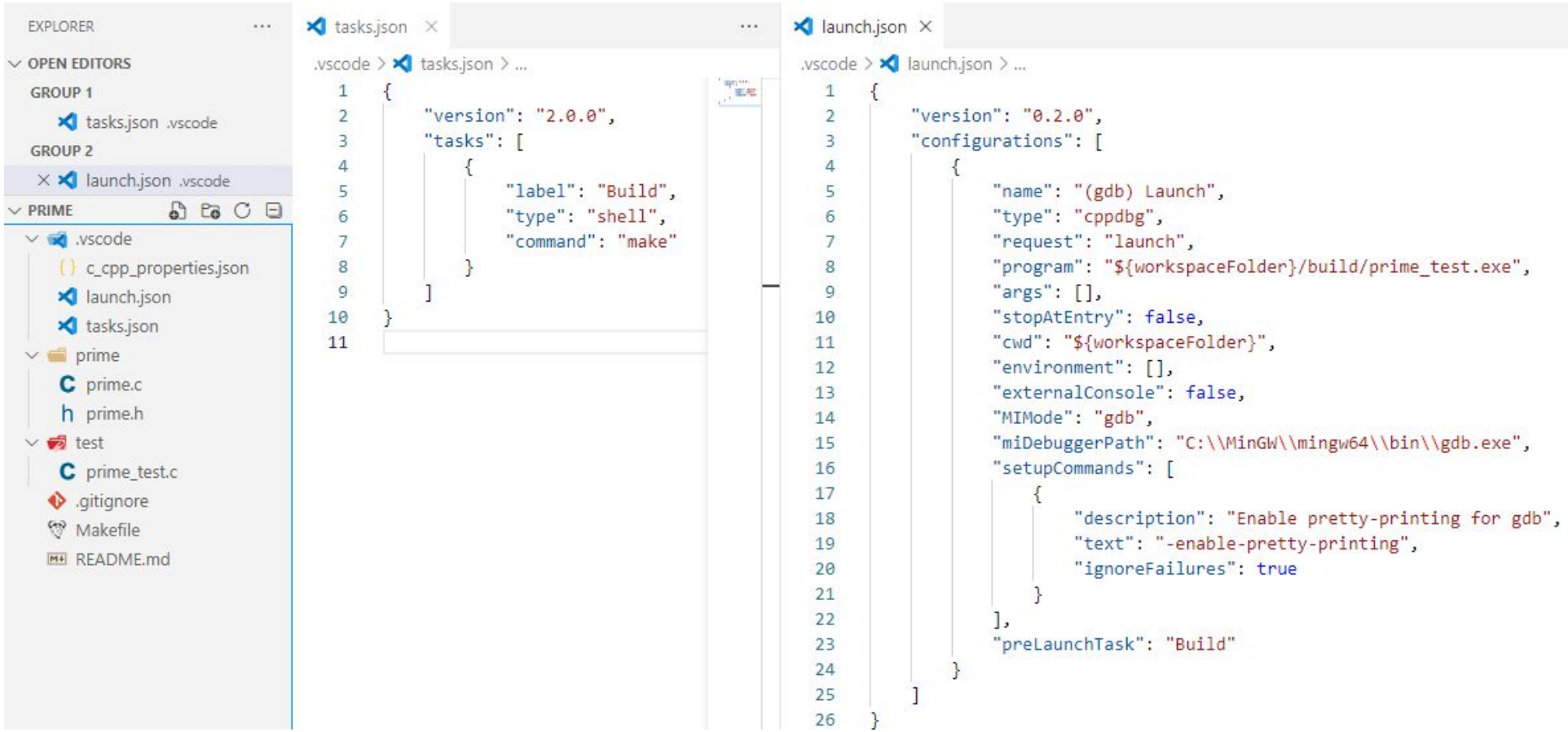

```c
#include <unity.h>
#include "prime.h"

/**
 * @brief This function is called before running every test function to initialize the environment for the test.
 *        For example if the module needs initialization or to start, we can do it in this function,
 *        or reseting the required variables for the test.
 */
void setUp(void) {}

/**
 * @brief This function is called after running every test function to cleanup the environment.
 *        For example if the module needs to free memory, to be stoped, or etc. we can do it in this function
 */
void tearDown(void) {}

// This is a test function. In these test cases we are going to check for prime numbers
void test_prime_numbers(void)
{
    TEST_ASSERT_TRUE(prime_check(2));
    TEST_ASSERT_TRUE(prime_check(3));
    TEST_ASSERT_TRUE(prime_check(23));
}

// This is another test case. In these test cases we are going to check for non-prime numbers
void test_non_prime_numbers(void)
{
    TEST_ASSERT_FALSE(prime_check(0));
    TEST_ASSERT_FALSE(prime_check(1));
    TEST_ASSERT_FALSE(prime_check(20));
    TEST_ASSERT_FALSE(prime_check(1000));
}

int main(void)
{
    UNITY_BEGIN(); // Start Unity

    // Run test functions
    RUN_TEST(test_prime_numbers);
    RUN_TEST(test_non_prime_numbers);

    return UNITY_END(); // End Unity
}
```

GDB

- Debugging is the process of finding and resolving problems within a program using a debugger.
- **GDB** is the GNU Project debugger which can be used to debug programs written in C language.
- To compile your program for debugging you need to use **-g**. E.g. ***gcc -g main.c -o main***
- You can use **gdb** to debug your program in command line or in Visual studio code.
- To use gdb & gcc to build, debug and run in visual studio code
  - Click on the run icon and then click on the **Run and Debug** button
  - Select C++(GDB/LLDB) in the opened list. And then Select **Default Configuration**
  - A json file (**launch.json**) is opened. Then set the path to your program: "program": "path/to/your/program"
  - Then set the path of the debugger(gdb): "miDebuggerPath": "C:\\MinGW\\mingw64\\bin\\gdb.exe"
  - To make a task to compile & run your program click on **Terminal > Configure Tasks..** in the main menu.
  - Then click on **Create tasks.json file from template** and then **Others Examples to run an arbitrary external command**.
  - The **tasks.json** file is created. Change the label from **echo** to **Build**
  - In the **command** write the shell commands to compile and run your program.
  - Then open **launch.json** and add "preLaunchTask": "Build" to the **configurations**.

Visual Studio Code - GDB

- An example of launch.json and tasks.json



Exercise 10 - TDD

Using TDD develop a linked list module of unique and sorted elements.

The module name shall be **list** and here you have the header file of the module.

```
#ifndef LIST_H
#define LIST_H

#include <stddef.h>
#include <stdbool.h>

// This function is used to insert data in the list. It returns true if value is unique and inserted successfully; otherwise false
bool list_insert(int data);

// This function returns number of the nodes in the list.
size_t list_available(void);

// This function is used to search for a value in the list. It returns 0 if data is not in the list; otherwise the position of the data in the list.
size_t list_find(int data);

// This function is used to get the data stored in the nth node. n is the nth element. n shall be a valid position and greater than 0. It returns
// false  if n is not valid; otherwise true. The data stored in the nth node will be stored in the variable whose address is passed as ptr.
bool list_get_data(size_t n, int *ptr);

// This function is used to change data in the list. It returns false if old_data does not exist or new_data already exists; otherwise true
bool list_edit(int old_data, int new_data);

// This function is used to delete an element in the list. It returns false if data does not exist; otherwise true
bool list_delete(int value);

// This function is used to destroy the list and free the allocated memory.
void list_destroy(void);

#endif /* LIST_H */
```

Software Testing

- Some useful links
  - Software Testing Tutorial: Free Course
  - Software Testing Fundamentals
  - The Three Laws of TDD
  - What Is Software Testing?
  - The Three Laws of TDD (Featuring Kotlin)
  - How TDD is related to the quality of code
  - What is Test Driven Development?
  - What is Behavior Driven Development?
  - TDD vs BDD. Giants of Test Go Head-to-Head (1)
  - TDD vs BDD. The Giants of Test Go Head-to-Head (2)
  - TDD vs BDD - Your free CHEAT SHEET
  - TDD and BDD - What Are The Key Differences?