



Unit Testing in Python

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Python Unit Test Libraries

Doctest - tests in code provide documentation

Unittest - the standard library, based on JUnit

Pytest - simple yet powerful package for concise tests. Can execute doctests & unittests, too.

Libraries to Enhance Tests

Mock objects - "fake" objects for external components

- also called "test doubles"

Hamcrest - declarative rules of "intent" to help write readable, powerful matching rules for tests.

Good Overview of Unit Testing

Getting Started with Testing in Python (on RealPython)

`https://realpython.com/python-testing/`

unittest example

```
import unittest
```

class extends TestCase

```
class TestBuiltins(unittest.TestCase):
```

```
    """Test some python built-in methods"""
```

```
    def test_len(self):
```

```
        self.assertEqual(5, len("hello"))
```

```
        self.assertEqual(7, len(" el lo "))
```

```
        self.assertEqual(0, len("")) # edge case
```

```
    def test_isupper(self):
```

```
        self.assertTrue("ABC".isupper())
```

```
        self.assertFalse("ABc".isupper())
```

Test method name must begin with **test_**

How to Write an "assert"

docstring will be
shown on test output

expected result

actual result

```
def test_len(self):  
    """length of a string is number of chars"""  
    self.assertEqual(5, len("hello"))
```

should be True

```
def test_isupper(self):  
    self.assertTrue( "ABC".isupper() )  
  
    self.assertFalse( "ABc".isupper() )
```

should be False

Run tests from the command line

Run all tests or just specific tests.

```
cmd> python -m unittest test_module
```

```
cmd> python -m unittest tests/test_module.py
```

```
# print verbose test results
```

```
cmd> python -m unittest -v test_module
```

```
# auto-discovery: run all test_*.py files
```

```
cmd> python -m unittest
```

```
# print help
```

```
cmd> python -m unittest -h
```

Other Ways to Run tests

1. Use your IDE run the tests.
2. Use a test script or **build tool**.
3. Add a "main" block to your Test file...

```
import unittest

...

if __name__ == "__main__":
    unittest.main()    # or unittest.main(verbose=2)
```

Exercise: Try it Yourself

Test `math.sqrt()` and `math.pow()`.

```
import unittest
import math

class MathTest(unittest.TestCase):
    def test_sqrt(self):
        self.assertEqual(5, math.sqrt(25))
        self.assertEqual(0, math.sqrt(0)) #edge case

    def test_pow(self):
        #TODO Write 1 or 2 tests of math.pow(x,n)
```


Exercise: Run Your Tests

Run on the command line:

```
cmd> python -m unittest test_math
```

```
..
```

```
-----  
Ran 2 tests in 0.001s
```

Run with verbose (-v) output

```
cmd> python -m unittest -v test_math.py
```

```
test_sqrt (test_math.MathTest) ... ok
```

```
test_pow (test_math.MathTest) ... ok
```

```
-----  
Ran 2 tests in 0.001s
```

Exercise: Write two **Failing** Tests

```
import unittest
import math

class MathTest(unittest.TestCase):
    # This answer is WRONG. Test should fail.
    def test_wrong_sqrt(self):
        self.assertEqual(10.0, math.sqrt(100.000001))

    # This is ILLEGAL. Cannot sqrt a negative value.
    def test_sqrt_of_negative(self):
        self.assertEqual(-4, math.sqrt(-16))
```

Exercise: Run the Tests

Run on the command line:

```
cmd> python -m unittest math_test.py
..EF
=====
ERROR: test_sqrt_of_negative (math_test.MathTest)
-----

Traceback (most recent call last):
  File "test_math.py", line 10, in test_sqrt_negative
    self.assertEqual(4, math.sqrt(-16))
ValueError: math domain error
=====
FAIL: test_wrong_sqrt (test_math.MathTest)
Trackback (most recent call last):
AssertionError: 1 != 5.0
```

Test Results

At the end, unittest prints:

```
Ran 4 tests in 0.001s  
FAILED (failures=1, errors=1)
```

How are "failure" and "error" different?

Failure means a test condition (assertion) failed

`assertEquals(except, actual)`

`fail("it didn't work")`

expected an exception, but exception not raised

Error means some code caused an error

Tests Outcomes

Success: passes all "assert"

Failure: fails an "assert" but code runs OK

Error: error while running test, such as exception raised

What Can You assert?

```
assertTrue( gcd(-3,-5) > 0 )
assertFalse( "hello".isupper() )
assertEqual( 9, math.pow(3,2) )
assertNotEqual( "a", "b")
assertIsNone(a)                # test "a is None"
assertIsNotNone(a)             # test "a is not None"
assertIn(a, list)              # test "a in list"
assertIsInstance(3, int)       # test 3 in an "int"
assertListEqual(list1, list2) # all elements equal
```

Many more!

See "unittest" in the Python Library docs.

Use the Correct assert

Use the 'assert' that matches what you **want to test**.

Good asserts (matches what you want to verify):

```
assertEqual( 5, math.sqrt(25))  
assertGreater( math.pi, 3.14159)  
assertNotIn('a', ['yes', 'no', 'maybe'])
```

Don't write this:

```
assertTrue(5 == math.sqrt(25))  
assertIs(math.pi > 3.14159, True)  
assertTrue( math.pi > 3.14159 )  
assertFalse('a' in ['yes', 'no', 'maybe'])
```

Test involving Floating Point

Calculations using floating point often result in *rounding error* or *precision error*.

Use `assertAlmostEqual` to test a result which may have *rounding error*:

```
def test_with_limited_precision( self ):  
    self.assertAlmostEqual(  
        2.33333333, average([1,2,4]), places=8)
```

```
# delta = allowed difference in values  
self.assertAlmostEqual(  
    0.33333, 1.0/3.0, delta=0.5e-4)
```


Skip a Test or Fail a Test

```
import unittest

class MyTest(unittest.TestCase):

    @unittest.skip("Not done yet")
    def test_add_fractions(self):
        pass

    def test_fraction_constructor(self):
        self.fail("Write this test!")
```

Test for Exception

What if your code should throw an exception?

```
def test_sqrt_of_negative( self ) :  
    """sqrt of a negative number should throw  
        ValueError.  
    """  
  
    self.assert????( math.sqrt(-1) )
```

Test for Exception

`assertRaises` expects a block of code to raise an exception:

```
def test_sqrt_of_negative(self):  
    with self.assertRaises(ValueError):  
        x = math.sqrt(-1)
```

Exercise: use `assertRaises`

Add `assertRaises` expects to your `sqrt` test:

```
def test_sqrt_of_negative(self):  
    with self.assertRaises(ValueError):  
        result = math.sqrt(-1)  
        result2 = math.log(-4) # not reached
```

Can we do this?

`assertRaises` with extra argument:

```
def test_sqrt_of_negative(self):  
    self.assertRaises(ValueError, math.sqrt(-1))
```

This **doesn't work**.

A `ValueError` exception is thrown (the test fails).

Which Operation is Done 1st, 2nd, ..?

```
print("sqrt 5 + 1 is", 1 + math.sqrt(5))
```

Which operation is done first?

```
def test_sqrt_of_negative(self):  
    self.assertRaises(ValueError, math.sqrt(-1))
```

Python evaluates `math.sqrt(-1)` before calling `assertRaises`.

So it raises an uncaught exception.

The Python Docs State:

```
assertRaises(exception, callable, *args, **kwargs)
```

What is a *callable*?


Something that you can call. :-)

Example: a function, a lambda expression

Use a callable in assertRaises

assertRaises with callable:

```
def test_sqrt_of_negative(self):  
    self.assertRaises(ValueError, math.sqrt, -1)
```



*args passed to the callable

Don't test multiple exceptions in one "assertRaises" block

The Cash class constructor should raise exception if

- a) value (1st param) is negative
- b) currency (2nd param) is an empty string

This test will fail to detect some errors. Why?

```
def test_cash_constructor(self):  
    with self.assertRaises(ValueError):  
        c1 = Cash(-1, "Baht")  
        c2 = Cash(10, "")
```

What to Name Your Tests?

1. **Test methods** begin with `test_` and use **snake case**.

```
def test_sqrt(self)
```

```
def test_sqrt_of_negative_value(self)
```

2. **Test class name** either starts with `Test` (Python style) or ends with `"Test"` (JUnit style). Use **CamelCase**.

```
class TestMath(unittest.TestCase)
```

```
class MathTest(unittest.TestCase)
```

What to Name Your Tests?

3. **Test filename** should start with `test_` & use snake case

`test_math.py`

`test_list_util.py` or `test_listutil.py`

Note:

if test filename ends with `_test` like `math_test.py` then Python's "test discovery" feature won't discover the tests unless you use `-p` ("pattern"):

```
python -m unittest -p "*_test.py"
```

Exercise: Test Driven Development

Write some tests for this function before you write the function code. Just return 0:

```
def average( lst ) :  
    """Return average of a list of numbers"""  
    return 0
```

What is Test Driven Development

Write the tests before you write the code to test.

1. Write a test or a small number of tests.
2. Run tests. They all fail.
3. Write **just enough** code to make the tests pass
...but not more code.

Repeat.

TDD: Define Test Cases

1. **Typical case**: list contains a few numbers
2. **Edge cases**:
 - a) list with only 1 number,
 - b) list with many values all the same,
 - c) list containing some 0 values (changes average).
3. **Illegal case**: empty list

*What should happen in this case??***

TDD forces you to think about
what the code *should do*.

***Hint: Python has a builtin `max(list)` function.*

Use it as an example.

TDD: Write the Tests

10 minutes

File: test_average.py

```
import unittest
from listutil import average
class TestAverage(unittest.TestCase):
    def test_average_singleton_list(self):
        self.assertEqual( 5, average([5]) )

    def test_list_with_many_values(self):
        # test average of many values

    def test_average_of_empty_list(self):
        # test that average([]) throws exception
```


TDD: Run Your Tests

```
cmd> python -m unittest test_average.py
```

```
FFF
```

```
-----
```

```
Ran 3 tests in 0.001s
```

```
FAILED (failures=3)
```

The tests should all **fail**.

TDD: Write `average()`

Write the code for `average()` so it passes all tests.

Do you feel any difference while coding?

Test setUp - Stack Example

- ❑ A **Stack** implements common stack data structure.
- ❑ You can push(), pop(), and peek() elements.
- ❑ Throws **StackException** if you do something stupid.

Stack
+ Stack(capacity)
+ capacity(): int
+ size(): int
+ isEmpty(): boolean
+ isFull(): boolean
+ push(T): void
+ pop(): T
+ peek(): T

Stack Tests all Need a Stack

In each test we need to create a new stack.

That's a lot of **duplicate code**.

How to eliminate duplicate code?

```
def test_new_stack_is_empty(self):  
    stack = Stack(5)  
    self.assertTrue( stack.isEmpty() )  
  
def test_push_and_pop(self):  
    stack = Stack(5)  
    stack.push("foo")  
    self.assertEqual("foo", stack.pop() )  
    self.assertTrue( stack.isEmpty() )
```

In unit testing, what is `setUp()` ?

What is the purpose of `setUp`?

- * create a "test fixture" containing objects or whatever your tests need
- * avoids redundant code in many tests
- * `TestCase` invokes it automatically before each test.

In JUnit 3: also called `setUp()`

In JUnit 4/5 use annotations instead:

```
public void prepareForTest() { ... }
```

Use setUp() to create test fixture

setUp() is called **before each test**.

```
import unittest

class StackTest(unittest.TestCase):
    # Create a new test fixture before each test
    def setUp(self):
        self.capacity = 5
        self.stack = Stack(capacity)

    def test_new_stack_is_empty(self):
        self.assertTrue( self.stack.isEmpty() )
        self.assertFalse( self.stack.isFull() )
        self.assertEqual( 0, self.stack.size() )
```

How to clean up after each test ?

Example: you read test data from a file.

You should close the file after each test.

Example: your tests write data to a file.

You want to delete the file after each test.

Answer: `tearDown ()`

Use tearDown() to clean up after test

tearDown() is called **after each test**. Its not usually needed, since setUp will re-initialize a test fixture.

```
class FileTest(unittest.TestCase):  
  
    def setUp(self):  
        # open file containing test data  
        self.file = open("testdata", "r")  
  
    def tearDown(self):  
        self.file.close()
```


Only Done Once Per Run

There is a method you can use to initialize the TestCase class before any tests are run.

This is done only once and its a class method.

Example: open a database or network connection one time before running any of the tests.

What is the method?

```
@classmethod
```

```
def setUpClass(cls):
```

Doctest

Include runnable code inside Python DocStrings.

Provides example of how to use the code
and executable tests!

```
def average(lst):  
    """Return the average of a list of numbers.  
  
    >>> average([2, 4, 0, 4])  
    2.5  
    >>> average([5])  
    5.0  
    """  
    return sum(lst)/len(lst)
```

doctest
comments

Running Doctest

Run doctest using command line:

```
cmd> python -m doctest -v listutil.py
2 tests in 5 items.
2 passed and 0 failed.
Test passed.
```

Or run doctest in the code:

```
if __name__ == "__main__":
    import doctest
    doctest.testmod(verbose=True)
```

Testing is Not So Easy!

These examples are *trivial* tests to show the syntax.

Real tests are more thoughtful and demanding.

Designing good tests makes you **think** about what the code should do, and what may go wrong.

Good tests are often **short**... but many of them.

References

Python Official Docs - easy to read, many examples

<https://docs.python.org/3/library/unittest.html>

Real Python good explanation & how to run unit tests in IDE

<https://realpython.com/python-testing/>

Video shows how to use unittest

<https://youtu.be/6tNS--WetLI>

Extensive List of Testing Tools for all kinds of testing

<https://wiki.python.org/moin/>

PythonTestingToolsTaxonomy