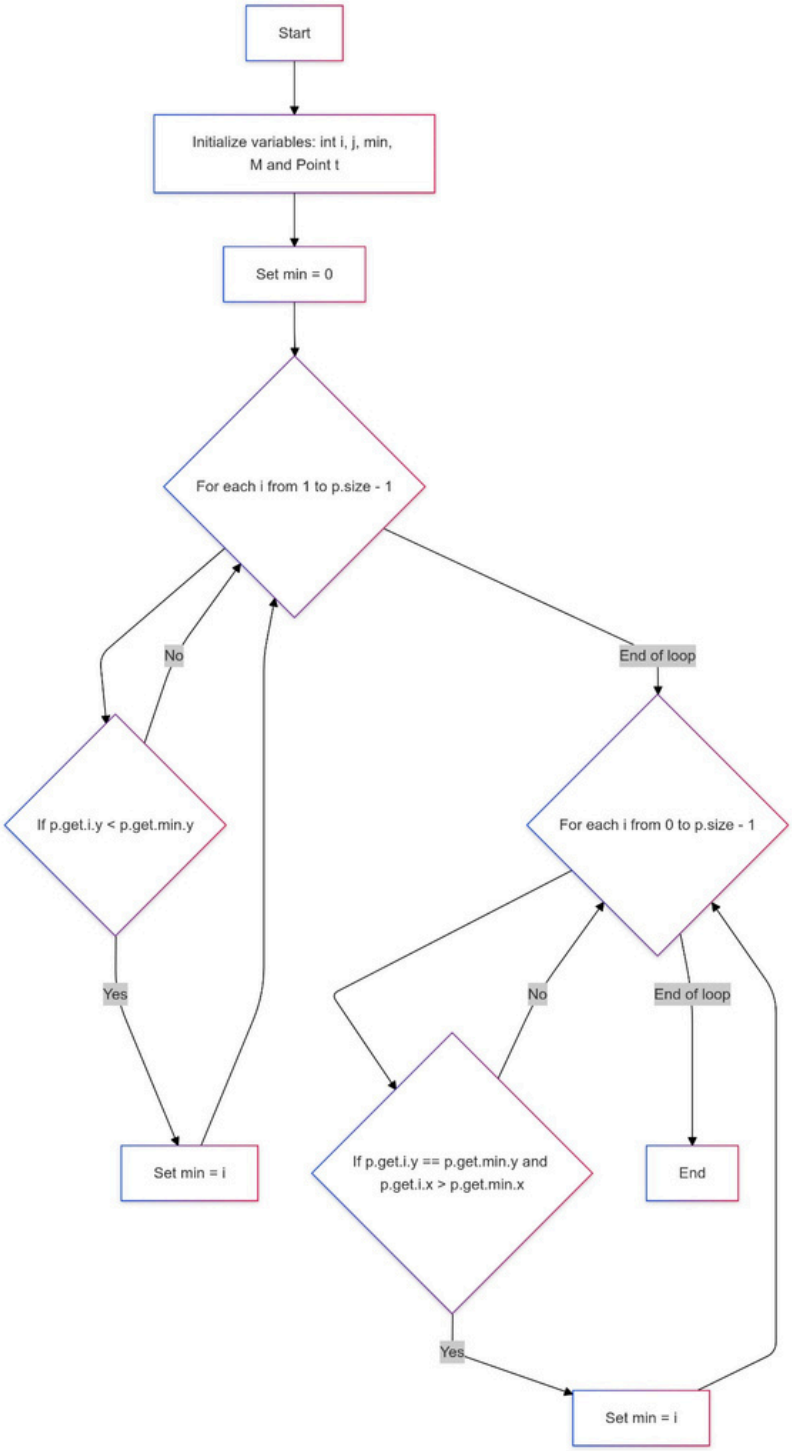
Q1)

```
class Point:
   def init(self, x, y):
self.x = x self.y =
y                class
ConvexHull:
   def do_graham(self, points):
      min_index = 0
      # Search for minimum y-coordinate (and lowest x-coordinate if y's are the same)
      for i in range(1, len(points)):
         if points[i].y < points[min_index].y:
            min_index = i
      # Continue along the values with the same y component
      for i in range(len(points)):
         if points[i].y == points[min_index].y and points[i].x > points[min_index].x:
            min_index = i
      return min_index # Returning min index for verification purposes
# Example usage
if name == "main":
   points = [Point(0, 0), Point(1, 1), Point(2, 2), Point(1, 0)]
   convex_hull = ConvexHull()
   min_index = convex_hull.do_graham(points)
   print(f"The index of the minimum point is: {min_index}")
   print(f"The minimum point is: ({points[min_index].x}, {points[min_index].y})")
```

Q2)


Start
Initialize variables: int i, j, min, M and Point t
Set min = 0
For each i from 1 to p.size - 1
No
End of loop
If p.get.i.y < p.get.min.y
For each i from 0 to p.size - 1
Yes
No
End of loop
Set min = i
If p.get.i.y == p.get.min.y and p.get.i.x > p.get.min.x
End
Yes
Set min = i

Q3)

Statement Coverage

Objective: Ensure each line of code is executed at least once.

To achieve statement coverage:

1. We need to run the code through both for loops and satisfy all if conditions at least once.

Test Case for Statement Coverage

Test Case 1:

- **Input:** `p = [Point(2, 3), Point(4, 1), Point(5, 2)]`
- **ExpectedOutput:** min = 1
  This test case will:
  - Executethefirstforloopandtheifconditiontofindthesmallesty.
  - Thesecondloopwillalsorun,butnotiewilloccur.

Test Case 2 (for Tie Case):

- **Input:** `p = [Point(2, 3), Point(4, 1), Point(3, 1), Point(5, 2)]`
- **ExpectedOutput:** min = 2
  This test case will:
  - Executebothloopsandtriggertheifconditioninthesecondloopto handle a tie on y by choosing the point with the larger x.

These two test cases cover each line of code, fulfilling **Statement Coverage**.

b. Branch Coverage

Objective: Ensure each branch (true/false for each condition) is covered.

To achieve branch coverage, we need to make sure each possible outcome (true/false) of each conditional expression is tested.

Test Case for Branch Coverage

We can use the same test cases as above, with some additions to ensure all branches are covered.

Test Case 1:

- **Input:** `p = [Point(2, 3), Point(4, 1), Point(5, 2)]`
- **ExpectedOutput:** min = 1

This case will:

- Coverthetrueandfalsebranchesofthefirstloop'sifstatement.

Test Case 2 (for Tie Case):

- **Input:** `p = [Point(2, 3), Point(4, 1), Point(3, 1), Point(5, 2)]`
- **ExpectedOutput:** min = 2

This case will:

- Coverbothtrueandfalsebranchesinthesecondloop'sifstatementtoresolve the tie by x.

Additional Test Case 3 (No Change in min):

- **Input:** `p = [Point(2, 3), Point(3, 3), Point(4, 3)]`
- **ExpectedOutput:** min = 0

This case will:

- Ensurethattheifconditionsdonottriggeranychangesinmin.

These test cases fulfill **Branch Coverage**.

c. Basic Condition Coverage

Objective: Ensure each basic condition within the expressions is evaluated to both true and false.
Each if statement has two basic conditions:

1. `(p.get(i).y < p.get(min).y)inthefirstloop.`

2. `(p.get(i).y == p.get(min).y)and(p.get(i).x > p.get(min).x)` in the second loop.

Test Cases for Basic Condition Coverage

Test Case 1 (Condition where y is less than minimum):

- **Input:**`p = [Point(2, 3), Point(4, 1), Point(5, 2)]`
- **ExpectedOutput:**min = 1

This case will:

- `Testp.get(i).y < p.get(min).y`tobetrue.

Test Case 2 (Condition where y is equal and x is greater):

- **Input:**`p = [Point(2, 3), Point(4, 1), Point(3, 1), Point(5, 2)]`
- **ExpectedOutput:**min = 2

This case will:

- `Testbothp.get(i).y == p.get(min).y`and`p.get(i).x >` p.get(min).x to be true.

Test Case 3 (Condition where both conditions are false):

- **Input:**`p = [Point(2, 3), Point(5, 3)]`
- **ExpectedOutput:**min = 0

This case will:

- Testbothconditionsinthesecondiftobefalse.

These three test cases provide **Basic Condition Coverage**, ensuring that each individual condition in the expressions has been tested with true and false values.

[*] Start mutation process:

- targets: point

- tests: test_points

[*] 3 tests passed:

- test_points [0.24341 s]

[*] Start mutants generation and execution:

-[# 1]COIpoint:

6:

7: def find_min_point(points):

8: min_index=0

9: foriinrange(1,len(points)):

-10: ifpoints[i].y<points[min_index].y:

+10: ifnot(points[i].y<points[min_index].y):

11: min_index=i

12: foriinrange(len(points)):

13: if(points[i].y==points[min_index].yandpoints[i].x>points[min_index].x):

14: min_index=i

[0.15408 s] killed by test_points.py::TestFindMinPointPathCoverage::testMultiplePoints

-[# 2]COIpoint:

9: foriinrange(1,len(points)):

10: ifpoints[i].y<points[min_index].y:

11: min_index=i

```
 12:     foriinrange(len(points)):
-13:         if(points[i].y==points[min_index].yandpoints[i].x>points[min_index].x):
+13:         ifnot((points[i].y==points[min_index].yandpoints[i].x>points[min_index].x)):
 14:             min_index=i
 15: returnpoints[min_index]
```

[0.14159 s] killed by test_points.py::TestFindMinPointPathCoverage::testMultiplePointSamyY

-[# 3]LCRpoint:

```
  9:     foriinrange(1,len(points)):
 10:         ifpoints[i].y<points[min_index].y:
 11:             min_index=i
 12:     foriinrange(len(points)):
-13:         if(points[i].y==points[min_index].yandpoints[i].x>points[min_index].x):
+13:         if(points[i].y==points[min_index].yorpoints[i].x>points[min_index].x):
 14:             min_index=i
 15: returnpoints[min_index]
```

[0.15599 s] killed by test_points.py::TestFindMinPointPathCoverage::testMultiplePointSamyY

-[# 4]RORpoint:

```
  6:
  7: def find_min_point(points):
  8: min_index=0
  9:     foriinrange(1,len(points)):
```

```
-10:         ifpoints[i].y<points[min_index].y:
+10:          ifpoints[i].y>points[min_index].y:
 11:             min_index=i
 12:     foriinrange(len(points)):
 13:         if(points[i].y==points[min_index].yandpoints[i].x>points[min_index].x):
 14:             min_index=i
```

[0.14234 s] killed by test_points.py::TestFindMinPointPathCoverage::testMultiplePoints

-[# 5]RORpoint:

```
  6:
  7: def find_min_point(points):
  8: min_index=0
  9:     foriinrange(1,len(points)):
-10:         ifpoints[i].y<points[min_index].y:
+10:          ifpoints[i].y<=points[min_index].y:
 11:             min_index=i
 12:     foriinrange(len(points)):
 13:         if(points[i].y==points[min_index].yandpoints[i].x>points[min_index].x):
 14:             min_index=i
```

[0.11556 s] survived

-[# 6]RORpoint:

```
  9:     foriinrange(1,len(points)):
```

```
 10:         ifpoints[i].y<points[min_index].y:
 11:             min_index=i
 12:     foriinrange(len(points)):
-13:         if(points[i].y==points[min_index].yandpoints[i].x>points[min_index].x):
+13:          if(points[i].y!=points[min_index].yandpoints[i].x>points[min_index].x):
 14:             min_index=i
 15: returnpoints[min_index]
```

[0.14255 s] killed by test_points.py::TestFindMinPointPathCoverage::testMultiplePointSamyY

-[# 7]RORpoint:

```
  9:     foriinrange(1,len(points)):
 10:         ifpoints[i].y<points[min_index].y:
 11:             min_index=i
 12:     foriinrange(len(points)):
-13:         if(points[i].y==points[min_index].yandpoints[i].x>points[min_index].x):
+13:          if(points[i].y==points[min_index].yandpoints[i].x<points[min_index].x):
 14:             min_index=i
 15: returnpoints[min_index]
```

[0.14933 s] killed by test_points.py::TestFindMinPointPathCoverage::testMultiplePointSamyY

-[# 8]RORpoint:

```
  9:     foriinrange(1,len(points)):
 10:         ifpoints[i].y<points[min_index].y:
```

```
 11:            min_index=i
 12:     foriinrange(len(points)):
-13:         if(points[i].y==points[min_index].yandpoints[i].x>points[min_index].x):
+13:          if(points[i].y==points[min_index].yandpoints[i].x>=points[min_index].x):
 14:            min_index=i
 15: returnpoints[min_index]
```

[0.11332 s] survived

Q4)

```
import unittest
from point import Point, findMinPoint

class TestFindMinPointPathCoverage(unittest.TestCase):

    def TestEmptyList(self):
        points = []
        with self.assertRaises(IndexError):
findMinPoint(points)

    def TestSinglePoint(self):
    points = [Point(2, 2)]
    result = findMinPoint(points)
    self.assertEqual(result, points[0])
    def testTwoUniquePoint(self):
        points = [Point(2, 1), Point(3, 2)]
        result = findMinPoint(points)
        self.assertEqual(result, points[0])
    def TestMultipleuniquePoint(self):
        points = [Point(1, 3), Point(2, 4), Point(3, 5)]
        result = findMinPoint(points)
        self.assertEqual(result, points[0])

    def testMultiplePointSamyY(self):
```

```
        points = [Point(1, 2), Point(3, 2), Point(2, 2)]
        result = findMinPoint(points)
        self.assertEqual(result, points[1])

    def testMultiplePoints(self):
        points = [Point(1, 2), Point(2, 2), Point(3, 1), Point(4, 1)]
        result = findMinPoint(points)
        self.assertEqual(result, points[3])

# Run the tests if this file is executed
if __name__ == "__main__":
    unittest.main()
```

Test Result with mut.py

Mutation score [1.52260 s]: 75.0%

- all: 8
- killed: 6 (75.0%)
- survived: 2 (25.0%)
- incompetent: 0 (0.0%)
- timeout: 0 (0.0%)