# 2.2.24

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August 31,2025

# Question

Show that the points $(1, 7)$, $(4, 2)$, $(-1, -1)$ and $(-4, 4)$ are the vertices of a square.

# Equation

For the points **ABCD** to represent a square:

$$\|AB\| = \|BC\| = \|CD\| = \|DA\| \tag{1}$$

$$\angle BAD = \angle ABC = \angle DCA = \angle ADC = 90 \tag{2}$$

# Theoretical Solution

Given details:

$$\mathbf{A} = \begin{pmatrix} 1 \\ 7 \end{pmatrix} \mathbf{B} = \begin{pmatrix} 4 \\ 2 \end{pmatrix} \mathbf{C} = \begin{pmatrix} -1 \\ -1 \end{pmatrix} \mathbf{D} = \begin{pmatrix} -4 \\ 4 \end{pmatrix} \tag{3}$$

# Theoretical Solution

Find the sides

$$\mathbf{AB} = \mathbf{B} - \mathbf{A} = \begin{pmatrix} 3 \\ -5 \end{pmatrix} \quad \mathbf{BC} = \mathbf{C} - \mathbf{B} = \begin{pmatrix} -5 \\ -3 \end{pmatrix} \tag{4}$$

$$\mathbf{CD} = \mathbf{D} - \mathbf{C} = \begin{pmatrix} -3 \\ 5 \end{pmatrix} \quad \mathbf{DA} = \mathbf{A} - \mathbf{D} = \begin{pmatrix} 5 \\ 3 \end{pmatrix} \tag{5}$$

# Theoretical Solution

Check side lengths

$$\|AB\| = \sqrt{\mathbf{AB}^T\mathbf{AB}} = \sqrt{3^2 + (-5)^2} = \sqrt{34} \tag{6}$$

$$\|BC\| = \sqrt{\mathbf{BC}^T\mathbf{BC}} = \sqrt{(-5)^2 + (-3)^2} = \sqrt{34} \tag{7}$$

$$\|CD\| = \sqrt{\mathbf{CD}^T\mathbf{CD}} = \sqrt{(-3)^2 + 5^2} = \sqrt{34} \tag{8}$$

$$\|DA\| = \sqrt{\mathbf{DA}^T\mathbf{DA}} = \sqrt{5^2 + 3^2} = \sqrt{34} \tag{9}$$

# Theoretical Solution

Therefore all the sides are of equal length

$$\|AB\| = \|BC\| = \|CD\| = \|DA\| \tag{10}$$

# Theoretical Solution

Condition for right angle: For two sides to be angled at 90 the Dot product between the 2 side vectors should be 0

$$= \mathbf{AB^T BC} = (3)(5) + (-5)(-3) = -15 + 15 = 0 \tag{11}$$

Therefore the sides are perpendicular to each other
Since all the sides are equal and one of the angles is 90 , all the points represent a square.

# C Code (1) - Function to store the points

```c
#include <stdio.h>

// Fill the array with square vertices: A(1,7), B(4,2), C(-1,-1),
    D(-4,4)
void get_square_points(double *points) {
    double coords[8] = {1,7, 4,2, -1,-1, -4,4};

    for (int i = 0; i < 8; i++) {
        points[i] = coords[i];
    }
}
```

# Python Code - Using Shared Object

```
import ctypes
import numpy as np
import matplotlib.pyplot as plt

# Load the shared object
square_lib = ctypes.CDLL("./square.so")

# Define function return type
square_lib.get_square_points.argtypes = [np.ctypeslib.ndpointer(
    dtype=np.double, ndim=1, flags="C")]
```

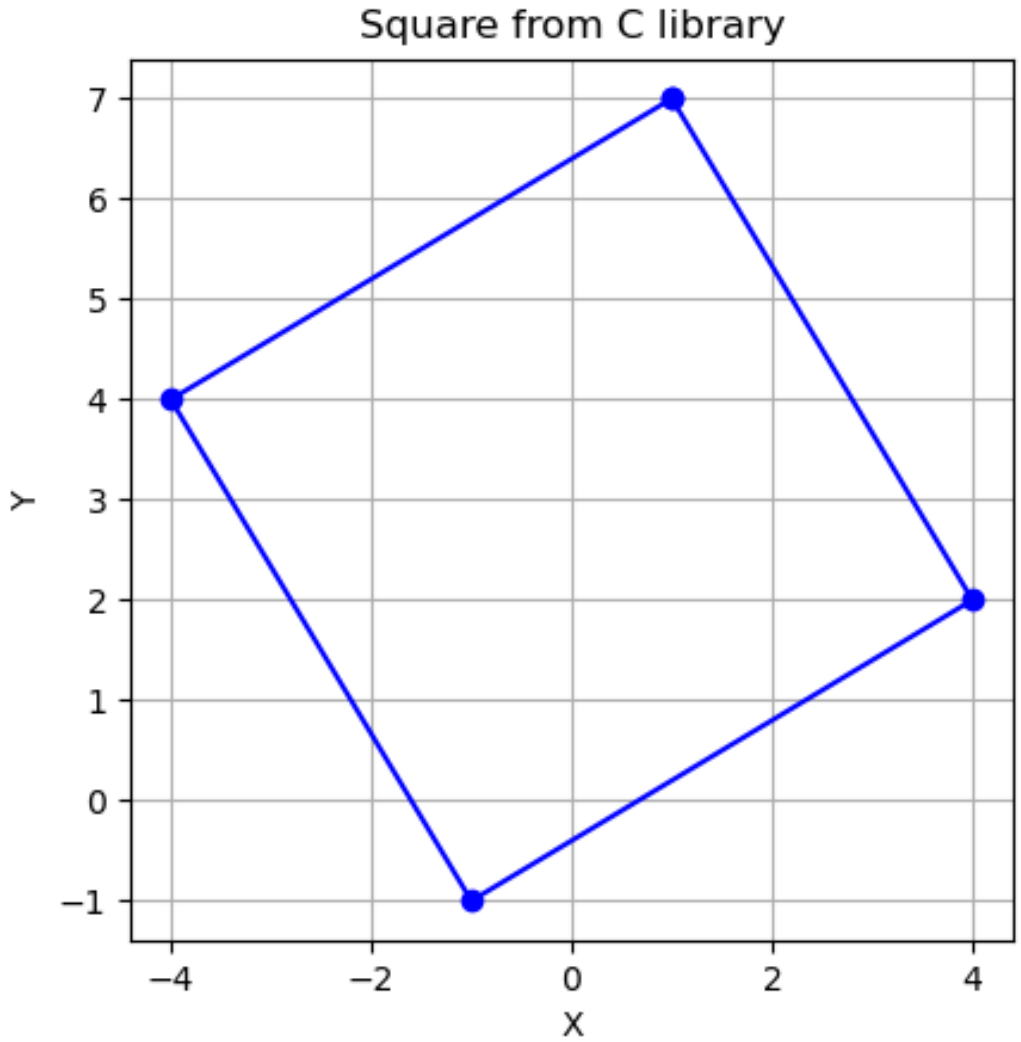
# Python Code - Using Shared Object

```
# Create numpy array to hold 8 values (x,y for 4 points)
points = np.zeros(8, dtype=np.double)

# Call C function to fill points
square_lib.get_square_points(points)

# Reshape into (4,2)
points = points.reshape((4,2))

# Close the square (repeat first point)
points = np.vstack([points, points[0]])
```

# Python Code - Using Shared Object

```
# Plot square
plt.plot(points[:,0], points[:,1], "bo-")
plt.title("Square from C library")
plt.xlabel("X")
plt.ylabel("Y")
plt.gca().set_aspect("equal")
plt.grid(True)
plt.savefig('figs/square.png')
subprocess.run(shlex.split("termux-open figs/sqaure.png")
```

# Plot-Using Both C and Python



# Python Code

```
import numpy as np
import matplotlib.pyplot as plt

# Define the square vertices
points = np.array([
    [1, 7], # A
    [4, 2], # B
    [-1, -1], # C
    [-4, 4] # D
])
```

# Python Code

```
# Close the square (repeat first point)
points = np.vstack([points, points[0]])

# Plot
plt.plot(points[:,0], points[:,1], "bo-", linewidth=2)
plt.title("Square of 4 Points")
plt.xlabel("X-axis")
plt.ylabel("Y-axis")
plt.gca().set_aspect("equal")
plt.grid(True)
plt.savefig('figs/square2.png')
subprocess.run(shlex.split("termux-open figs/distance.png")
```

# Plot-Using only Python