4.7.62

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Question

Find the equation of the plane which passes through the point (5, 2, -4) and perpendicular to the line with direction ratios 2, 3, -1.

Theoretical Solution

The plane passes through a known point,

$$\mathbf{A} = \begin{pmatrix} 5 \\ 2 \\ -4 \end{pmatrix}$$

The plane is perpendicular to a line with direction ratios (2, 3, -1).

$$\mathbf{n} = \begin{pmatrix} 2 \\ 3 \\ -1 \end{pmatrix}$$

The equation of a plane is given by the formula

$$\mathbf{n} = \begin{pmatrix} 2 \\ 3 \\ -1 \end{pmatrix}$$

, where $\mathbf{x}$ is a general point $[x, y, z]^T$ on the plane.

Theoretical Solution

Substituting the numerical values for our normal vector **n** and point **A**:

$$\begin{pmatrix} 2 & 3 & -1 \end{pmatrix} \left(\begin{pmatrix} x \\ y \\ z \end{pmatrix} - \begin{pmatrix} 5 \\ 2 \\ -4 \end{pmatrix} \right) = 0 \tag{1}$$

$$\implies \begin{pmatrix} 2 & 3 & -1 \end{pmatrix} \begin{pmatrix} x-5 \\ y-2 \\ z-(-4) \end{pmatrix} = 0 \tag{2}$$

$$\implies \begin{pmatrix} 2 & 3 & -1 \end{pmatrix} \begin{pmatrix} x-5 \\ y-2 \\ z+4 \end{pmatrix} = 0 \tag{3}$$

$$\implies 2(x-5) + 3(y-2) - 1(z+4) = 0 \tag{4}$$

$$\implies 2x - 10 + 3y - 6 - z - 4 = 0 \tag{5}$$

$$\implies 2x + 3y - z = 20 \tag{6}$$

Thus, the equation of the plane is $2x + 3y - z = 20$.

C Code

```c
#include<stdio.h>
typedef struct {
    double x, y, z;
} Vector;

typedef struct {
    double a, b, c, d;
} Plane;

Plane find_plane_from_point_and_normal(Vector point, Vector
    normal) {
    Plane result;
    result.a = normal.x;
    result.b = normal.y;
    result.c = normal.z;
    result.d = (normal.x * point.x) + (normal.y * point.y) + (
        normal.z * point.z);
    return result;
}
```

Python Code

```
import numpy as np
import matplotlib.pyplot as plt
from mpl_toolkits.mplot3d import Axes3D

point_A = np.array([5.0, 2.0, -4.0])
normal_n = np.array([2.0, 3.0, -1.0])

d = np.dot(normal_n, point_A)
plane_eq_str = f{normal_n[0]:.0f}x + {normal_n[1]:.0f}y + {normal_n[2]:.0f}z = {d:.0f}
print(fPlane equation: {plane_eq_str})

fig = plt.figure(figsize=(10, 8))
ax = fig.add_subplot(111, projection='3d')
```

Python Code

```
x_range = np.linspace(point_A[0] - 5, point_A[0] + 5, 20)
y_range = np.linspace(point_A[1] - 5, point_A[1] + 5, 20)
x_grid, y_grid = np.meshgrid(x_range, y_range)

z_plane = (d - normal_n[0] * x_grid - normal_n[1] * y_grid) /
    normal_n[2]

ax.plot_surface(x_grid, y_grid, z_plane, alpha=0.6, cmap='plasma'
    , edgecolor='none')

ax.scatter([point_A[0]], [point_A[1]], [point_A[2]], color='red',
     s=100, label=f'Point A {tuple(point_A)}')
```

Python Code

```
ax.quiver(
    point_A[0], point_A[1], point_A[2],
    normal_n[0], normal_n[1], normal_n[2],
    length=4, normalize=True, color='black', arrow_length_ratio
        =0.2,
    label=f'Normal Vector n={tuple(normal_n)}'
)

ax.set_xlabel('X-axis')
ax.set_ylabel('Y-axis')
ax.set_zlabel('Z-axis')
ax.set_title(f'Plane Visualization: {plane_eq_str}', fontsize=14)
ax.legend()
plt.grid(True)
plt.show()
```

Plot

figs/fig3.png