2.2.30

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Question

Find the angle between the line

$$\frac{x+1}{2} = \frac{y}{3} = \frac{z-3}{6} \tag{1}$$

and the plane

$$10x + 2y - 11z = 3. \tag{2}$$

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Theoretical Solution

Let us solve the given equation theoretically and then verify the solution computationally

According to the question,

Given a plane and line

Let θ be angle between plane and line

Then $90^\circ - \theta$ is angle between normal vector of plane and line

Let $\mathbf{D}$ be dirction vector of line and $\mathbf{n}$ be normal of plane

$$\mathbf{D} = \begin{pmatrix} 2 \\ 3 \\ 6 \end{pmatrix} \quad \mathbf{n} = \begin{pmatrix} 10 \\ 2 \\ -11 \end{pmatrix} \tag{3}$$

$$\cos(90^\circ - \theta) = \frac{\mathbf{D}^T \mathbf{n}}{\|\mathbf{n}\| \|\mathbf{D}\|} = \frac{-8}{21} \tag{4}$$

Theoretical Solution

$$\theta = 90^\circ - \cos^{-1}\left(\frac{-8}{21}\right) = -22.39^\circ \tag{5}$$

angle is 22.39°

C Code

```c
#include <stdio.h>
#include <math.h>

int main() {
    // Direction ratios of the line
    double dx = 2, dy = 3, dz = 6;

    // Normal vector of the plane
    double nx = 10, ny = 2, nz = -11;

    // Dot product of d and n
    double dot = dx * nx + dy * ny + dz * nz;

    // Magnitudes of d and n
    double mag_d = sqrt(dx*dx + dy*dy + dz*dz);
    double mag_n = sqrt(nx*nx + ny*ny + nz*nz);

    // Calculate the cosine of angle phi between d and n
    double cos_phi = fabs(dot) / (mag_d * mag_n);
```

C Code

```c
    // Calculate phi in radians
    double phi = acos(cos_phi);

    // Angle between line and plane
    double theta = (M_PI / 2) - phi;

    // Convert to degrees
    double angle_degrees = theta * (180.0 / M_PI);

    printf("The angle between the line and the plane is: %.2f
        degrees\n", angle_degrees);

    return 0;
}
```

python code

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

# Line: (x+1)/2 = y/3 = (z-3)/6
# Direction ratios of line
d = np.array([2, 3, 6])

# Plane: 10x + 2y - 11z = 3
n = np.array([10, 2, -11]) # normal vector of plane

# Angle between line and plane
# angle  = 90 - angle(line, normal)
cos_theta = abs(np.dot(d, n)) / (np.linalg.norm(d) * np.linalg.
    norm(n))
theta = np.arcsin(cos_theta) # angle between line and plane in
    radians
theta_deg = np.degrees(theta)
```

python code

```
print("Angle between line and plane = ", theta_deg, "degrees")

# ---------- Plotting ----------
fig = plt.figure()
ax = fig.add_subplot(111, projection='3d')

# Create grid for plane
xx, yy = np.meshgrid(range(-5, 6), range(-5, 6))
zz = (10*xx + 2*yy - 3) / 11 # from plane equation

# Plot plane
ax.plot_surface(xx, yy, zz, alpha=0.5, color='cyan')

# Line parametric form: x = -1 + 2t, y = 3t, z = 3 + 6t
t = np.linspace(-2, 2, 50)
x_line = -1 + 2*t
y_line = 3*t
z_line = 3 + 6*t
```

python code

```
# Plot line
ax.plot(x_line, y_line, z_line, color='red', linewidth=2, label="
    Line")

# Formatting
ax.set_xlabel('X')
ax.set_ylabel('Y')
ax.set_zlabel('Z')
ax.set_title(f"Angle = {theta_deg:.2f}")
ax.legend()

# Save the figure
plt.savefig("line_plane_angle.png", dpi=300)
plt.show()
```

Plot