1.2.29

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August 28,2025

Question

In a harbour, wind is blowing at the speed of 72 $\mathrm{km/h}$ and the flag on the mast of a boat anchored in the harbour flutters along the N–E direction. If the boat starts moving at a speed of 51 $\mathrm{km/h}$ to the north, what is the direction of the flag on the mast of the boat?

Represent given velocities as vectors

The wind velocity (ground frame) is along the NE direction with speed 72 km/h:

$$W = \begin{bmatrix} 72\cos 45^\circ \\ 72\sin 45^\circ \end{bmatrix} = \begin{bmatrix} 50.91 \\ 50.91 \end{bmatrix} \text{ km/h.}$$

The boat velocity (ground frame) is northward with speed 51 km/h:

$$V = \begin{bmatrix} 0 \\ 51 \end{bmatrix} \text{ km/h.}$$

Relative wind (wind as seen from the boat)

$$R = W - V = \begin{bmatrix} 50.91 \\ 50.91 \end{bmatrix} - \begin{bmatrix} 0 \\ 51 \end{bmatrix} = \begin{bmatrix} 50.91 \\ -0.09 \end{bmatrix}.$$

Direction of the relative wind

$$\theta = \tan^{-1}\left(\frac{-0.09}{50.91}\right) \approx -0.1^\circ$$

Thus, the relative wind is almost exactly eastward, slightly south of east.

The flag on the mast points nearly East, slightly tilted South.

C Code

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

int main() {
    double Rx = 50.91;
    double Ry = -0.09;

    double dot_product = Rx * 1 + Ry * 0; // dot with East vector
        [1, 0]
    double mag_R = sqrt(Rx * Rx + Ry * Ry);

    double cos_theta = dot_product / mag_R;
    double theta_rad = acos(cos_theta);
    double theta_deg = theta_rad * (180.0 / M_PI);

    printf(Angle from East = %.4f degrees\n, theta_deg);
    return 0;
}
```

Python Code

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

W = np.array([50.91, 50.91])
V = np.array([0, 51])
R = W - V
```

Python Code

```
origin = np.array([[0, 0], [0, 0]])

plt.figure(figsize=(8, 8))
plt.quiver(*origin,
           [W[0], V[0], R[0]],
           [W[1], V[1], R[1]],
           angles='xy', scale_units='xy', scale=1,
           color=['blue', 'green', 'red'],
           label=['Wind Vector ($\\vec{W}$)', 'Boat Vector ($\\vec
               {V}$)', 'Relative Wind ($\\vec{R}$)'])
```

Python Code

```
plt.xlim(-10, 80)
plt.ylim(-10, 80)
plt.axhline(0, color='gray', linestyle='--')
plt.axvline(0, color='gray', linestyle='--')
plt.gca().set_aspect('equal', adjustable='box')
plt.grid(True)
plt.legend()
```

Python Code

```
plt.title(Vector Plot: Wind, Boat, and Relative Wind)
plt.xlabel(East-West Direction)
plt.ylabel(North-South Direction)

plt.savefig(pythonimage.png, dpi=300)
plt.show()
```

Plot

figs/python image.png