Name:______________________________Class:__________________ Date:__________________

Two-Dimensional Motion and Vectors

Problem F

RELATIVE VELOCITY

PROBLEM

A polar bear swims 2.60 m/s south relative to the water. The bear is swimming against a current that moves 0.78 m/s at an angle of 40.0° north of west, relative to Earth. How long will it take the polar bear to reach the shore, which is 5.50 km to the south?

SOLUTION

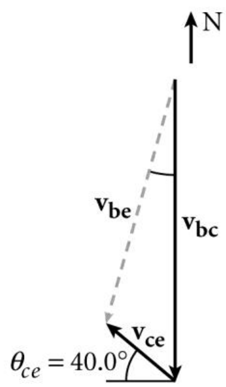
1. **DEFINE** **Given:** $\mathbf{v_{bc}}$ = 2.60 m/s due south (velocity of the *bear*, *b*, with respect to the *current*, *c*)

$\mathbf{v_{ce}}$ = 0.78 m/s at 40.0° north of west (velocity of the *current*, *c*, with respect to *Earth*, *e*)

Δy = 5.50 km, south

Unknown: Δt = ?

Diagram:



2. **PLAN** **Choose the equation(s) or situation:** To find $\mathbf{v_{be}}$, write the equation so that the subscripts of the vectors on the right begin with *b* and end with *e*.

$$\mathbf{v_{be}} = \mathbf{v_{bc}} + \mathbf{v_{ce}}$$

Because vectors $\mathbf{v_{bc}}$ and $\mathbf{v_{ce}}$ are not perpendicular, their *x* and *y* components must be calculated. Aligning the positive *y* axis with north and treating west as the positive *x* direction for convenience, the following equations apply for the magnitude of the components of $\mathbf{v_{be}}$.

$$v_{x,be} = v_{x,bc} + v_{x,ce} = v_{x,ce} = v_{ce}\,(\cos\,\theta_{ce})$$
$$v_{y,be} = v_{y,bc} + v_{y,ce} = -v_{bc} = v_{ce}\,(\sin\,\theta_{ce})$$

From these components the magnitude and direction of $\mathbf{v_{be}}$ could be found from the Pythagorean theorem and the tangent function, respectively. However, only the component $v_{y,be}$ is needed to calculate the time required for the bear to swim in the negative y direction.

$$\Delta t = \frac{-\Delta y}{v_{y,be}}$$

Rearrange the equation(s) to isolate the unknown(s):

$$\Delta t = \frac{-\Delta y}{v_{y,be}} = \frac{-\Delta y}{[-v_{bc} + v_{ce}(\sin \theta_{ce})]}$$

3. **CALCULATE** **Substitute the values into the equation(s) and solve:**

$$\Delta t = \frac{-5.50 \text{ km}}{(-2.60 \text{ m/s} + 0.78 \text{ m/s})(\sin 40.0°)]}$$

$$= \frac{-5.50 \text{ km}}{(-2.60 \text{ m/s} + 0.50 \text{ m/s})} = \frac{-5.50 \times 10^3 \text{ m}}{-2.10 \text{ m/s}}$$

$$\Delta t = \boxed{2.62 \times 10^3 \text{ s, or 43 min 40 s}}$$

4. **EVALUATE** Without the current, the polar bear would arrive about 500 s or 8.3 min sooner. The 500 s delay is about one fourth (25%) of the bear's swimming time without the current. This proportion is equal to the ratio of the current's northern component to the bear's velocity to the south.

ADDITIONAL PRACTICE

1. **A bird flies directly into a wind. If the bird's forward speed relative to the wind is 58.0 km/h and the wind's speed in the opposite direction is 55.0 km/h, relative to Earth, how long will it take the bird to fly 1.4 km?**
2. A moving walkway at an airport has a velocity of 1.50 m/s to the west. A man rushing to catch his flight runs down the walkway with a velocity of 4.20 m/s to the west relative to the walkway. If the walkway if 8.50×10^2 m long, how much time does the man save by running on the walkway as opposed to running on a non-moving surface?
3. The greatest average speed for a race car in the Daytona 500 is 286 km/h, which was achieved in 1980. Suppose a race car moving at this speed is in second place, being 0.750 km behind a car that is moving at a speed of 252 km/h. How long will it take the second-place car to catch up to the first-place car?
4. **A mosquito can fly with a speed of 1.10 m/s with respect to the air. Suppose a mosquito flies east at this speed across a swamp. The mosquito is flying into a breeze that has a velocity of 5.0 km/h with respect to Earth and moves 35° west of south. If the swamp is 540 m across, how long will it take the mosquito to cross the swamp?**

5. **A glider descends with a velocity relative to the air of 150 km/h at an angle of 7.0° below the horizontal. Suppose that the glider encounters an updraft with a velocity relative to Earth of 15 km/h upward. How long will it take the glider to reach the ground if it encounters the updraft at 166 m? How long would it take for the glider to land without the updraft?**
6. A flare gun is mounted on an automobile and fired perpendicular to the car's motion. The car's velocity with respect to Earth is 145 km/h to the north. The flare's velocity with respect to the car is 87 km/h to the west. What are the components of the flare's displacement with respect to Earth 0.45 s after the flare is launched?
7. **An airship moving north at 55.0 km/h with respect to the air encounters a wind from 17.0° north of west. If the wind's speed with respect to Earth is 40.0 km/h, what is the airship's velocity with respect to Earth?**
8. How far to the north and west does the airship in problem 7 travel after 15.0 minutes?
9. A torpedo fired at an anchored target moves against a current. Suppose the torpedo's velocity with respect to the current is 51 km/h east, and the current's velocity with respect to the target is 4.0 km/h south. If the torpedo hits the target in 14 s, how far away is the target from the point where the torpedo is launched? How far north of the target must the torpedo be launched in order to hit the target?
10. A sailboat travels south with a speed of 12.0 km/h with respect to the water. Suppose the boat encounters a current that has a velocity with respect to Earth of 4.0 km/h at 15.0° south of east. What is the sailboat's resultant velocity with respect to Earth?