Introduction to Mechanics
Relative Motion

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Feb 10, 2020

Last time

- relative motion examples

Overview

- lots more relative motion examples

Relative Motion

Observers A and B have different descriptions of the motion of particle P. We can relate these descriptions using vector addition.

$$\vec{\mathbf{v}}_{PA} = \vec{\mathbf{v}}_{PB} + \vec{\mathbf{v}}_{BA}$$

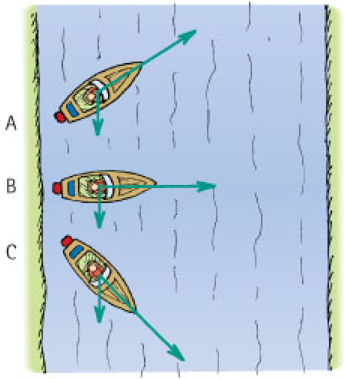
$\vec{\mathbf{v}}_{BA}$ is the velocity of observer B's frame *relative to* frame A.

If we want to think of how A moves relative to B, then we need to swap the subscripts. Swapping the subscripts flips the sign.

$$\vec{\mathbf{v}}_{AB} = -\vec{\mathbf{v}}_{BA}$$

Relative Motion Practice

Suppose the river is 50 m wide, the motorboats move at 5 m/s relative to the water, the river has a current of 1 m/s, and that boat A makes an angle of 30° to the horizontal and boat C makes an angle of 60° to the horizontal as shown in the picture.



(a) How long does it take each boat to cross?

(b) How far downstream is boat B when it reaches the opposite shore?

[1]Figure from Hewitt, "Conceptual Physics".

Another Boat Question

You are riding in a boat whose speed relative to the water is 6.1 m/s. The boat points at an angle of 25° upstream on a river flowing at 1.4 m/s. What is your velocity relative to the ground?

[1] Figure from Walker, "Physics".

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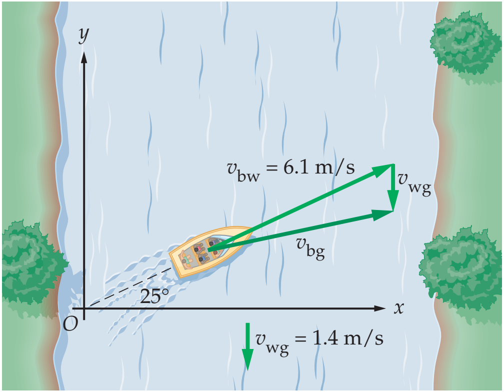
Sketch:



[1] Figure from Walker, "Physics".

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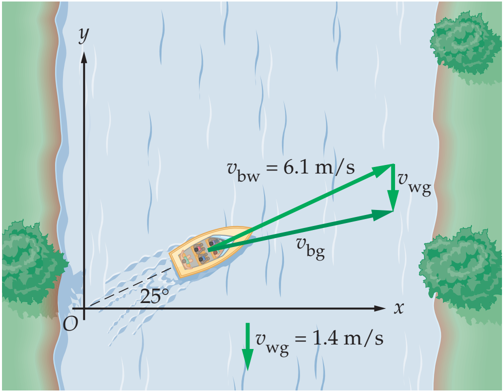

Hypothesis: Less than 6.1 m/s, but more than 6.1-1.4 = 4.7 m/s. The angle the velocity makes to the x-axis will be less than 25°.

[1]Figure from Walker, "Physics".

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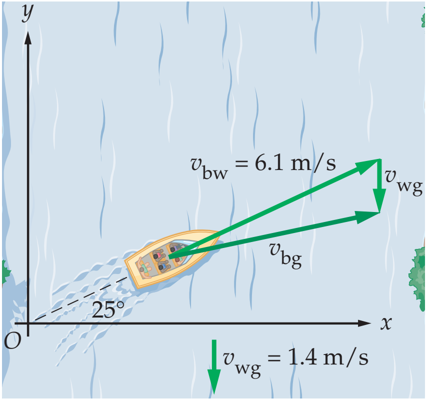

Strategy: Vector addition.

$$\vec{\mathbf{v}}_{bg} = \vec{\mathbf{v}}_{bw} + \vec{\mathbf{v}}_{wg}$$

[1] Figure from Walker, "Physics".

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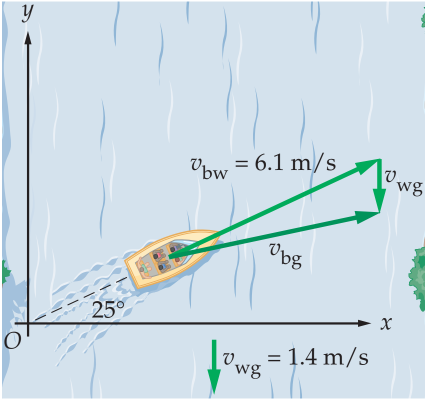

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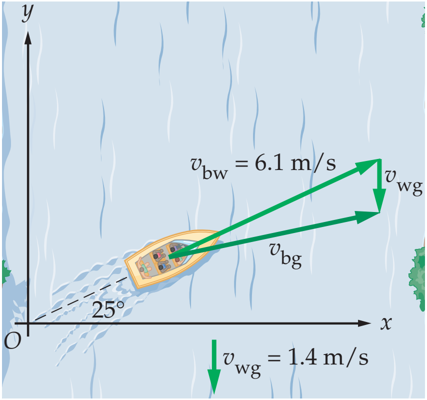
$$\vec{\mathbf{v}}_{bg} = \vec{\mathbf{v}}_{bw} + \vec{\mathbf{v}}_{wg}$$

x-components:

$$\begin{aligned} v_{bg,x} &= v_{bw,x} + 0 \\ &= (6.1\text{ m/s})\cos(25^\circ) \\ &= 5.528\text{ m/s} \end{aligned}$$

[1] Figure from Walker, "Physics".

Another Boat Question



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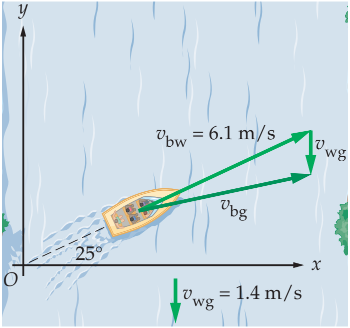
y-components:

$$\begin{aligned} v_{bg,y} &= v_{bw,y} + v_{wg,y} \\ &= (6.1 \text{ m/s}) \sin(25^\circ) \\ &\quad +(-1.4 \text{ m/s}) \\ &= 1.178 \text{ m/s} \end{aligned}$$

[1]Figure from Walker, "Physics".

Another Boat Question



Speed of boat relative to ground:

$$\begin{aligned} v_{bg} &= \sqrt{v_{bg,x}^2 + v_{bg,y}^2} \\ &= \sqrt{(5.528 \text{ m/s})^2 + (1.178 \text{ m/s})^2} \\ &= 5.653 \text{ m/s} \\ &= \underline{5.7 \text{ m/s}} \end{aligned}$$

Direction angle

$$\begin{aligned} \theta &= \tan^{-1}\left(\frac{v_{bg,y}}{v_{bg,x}}\right) \\ &= \tan^{-1}\left(\frac{1.178}{5.528}\right) \\ &= \underline{12^\circ \text{ upstream / counterclockwise}} \\ &\qquad \underline{\text{from my } x \text{ axis}} \end{aligned}$$

[1]Figure from Walker, "Physics".

Relative Motion Practice

You are riding on a Jet Ski at an angle of 35° upstream on a river flowing with a speed of 2.8 m/s. If your velocity relative to the ground is 9.5 m/s at an angle of 20.0° upstream, what is the speed of the Jet Ski relative to the water?

(Note: Angles are measured relative to the x axis, which points across the river.)

[1] Walker, "Physics", ch 3, problem 55.

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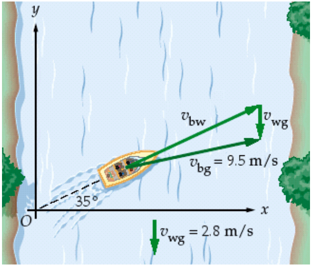

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Summary

- relative motion

Homework

- relative motion question on next slide (don't hand in)
- relative motion worksheet (answer on scantron and hand in, due Thurs)

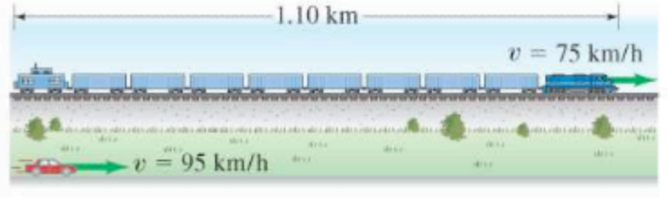
Walker Physics:

- Ch 3, onward from page 76. Problems: 49, 51, 53*, 57

*There is a mistake in the vector diagram answer in the back of the book. It looks like $v_{pg} = 340$ km/h, but as it says in the question, the airspeed $v_{pa} = 340$ km/h, so $v_{pg} \neq 340$ km/h.

Extra Homework Question

An automobile traveling 95 km/h overtakes a 1.10-km-long train traveling in the same direction on a track parallel to the road. If the train's speed is 75 km/h, how long does it take the car to pass it, and how far will the car have traveled in this time? What are the results if the car and train are traveling in opposite directions?



[1] Giancoli, "Physics: Principles with Applications", 6th ed, page 43.

Ans: 3.3 min, 5.2 km; 23 s, 0.61 km