PHYSICS IN MOTION
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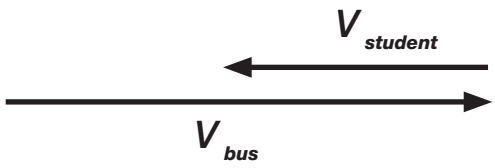
Unit 2F
Relative Velocity
Practice Problems TEACHER

Work each of the following problems. SHOW ALL WORK.

1. **A school bus moves at 15 m/s relative to an outside observer. If a student walks toward the front of the bus at 3 m/s relative to the bus, how fast is the student moving relative to the observer?**

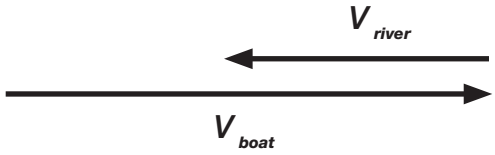
$$v_{result} = v_{bus} + v_{student}$$
$$v_{result} = 15\,{}^{m}/_{s} + 3\,{}^{m}/_{s}$$
$$v_{result} = 18\,{}^{m}/_{s}$$

2. **If the same student turns around and walks to the back of the bus at 3 m/s, what is the relative velocity of the student to the observer?**



$$v_{result} = v_{bus} - v_{student}$$
$$v_{result} = 15\,{}^{m}/_{s} - 3\,{}^{m}/_{s}$$
$$v_{result} = 12\,{}^{m}/_{s}$$

3. **A freighter needs to travel up the Savannah River to the port, moving against the flow of the water. If the river flows at 3 m/s relative to the shore, and the maximum speed of the freighter relative to the river is 7 m/s, what is the maximum velocity of the freighter relative to the shore?**



$$v_{result} = v_{boat} - v_{river}$$
$$v_{result} = 7\,{}^{m}/_{s} - 3\,{}^{m}/_{s}$$
$$v_{result} = 4\,{}^{m}/_{s}$$

4. **In some track and field events, very fast times may not count as world records due to a prevailing tailwind at the runners' backs. The limit for the tailwind that can be present is 2 m/s.**
   a. **If an athlete runs a 100-meter dash at an average speed of 9 m/s, how long will it take for him to run the full 100 meters?**

$$v = \frac{d}{t}$$
$$9\,{}^{m}/_{s} = \frac{100\,m}{t}$$
$$t = \frac{100\,m}{9\,{}^{m}/_{s}}$$
$$t = 11.1\,s$$

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b. What will be his speed relative to the ground if he encounters a 2 m/s tailwind?

$$v_{result} = v_{runner} + v_{wind}$$
$$v_{result} = 11.1\ ^{m}/_{s} + 2.0\ ^{m}/_{s}$$
$$v_{result} = 13.1\ ^{m}/_{s}$$

c. What will be his new time if he encounters a 2 m/s tailwind?

$$v = \frac{d}{t}$$
$$13.1\ ^{m}/_{s} = \frac{100\ m}{t}$$
$$t = \frac{100\ m}{13.1\ ^{m}/_{s}}$$
$$t = 7.63\ s$$

5. A flight from Atlanta to Los Angeles takes 5 hours to travel a distance of 3,117 km. The flight back from Los Angeles to Atlanta is the same distance, but takes only 4 hours and 20 minutes. What does this indicate to you about the direction of the wind that the plane encounters during these flights?

Because the flight from east to west is longer than the flight from west to east, it can be determined that the wind travels from west to east, causing a headwind on the westbound flight and a tailwind on the eastbound flight.

6. If the plane in the previous question travels from Atlanta to Los Angeles at 670 km/h relative to the air around it, how fast is the air moving relative to the ground?

$$v_{result} = \frac{d}{t}$$
$$v_{result} = \frac{3\,117\ km}{5\ h}$$
$$v_{result} = 623.4\ ^{km}/_{h}$$

$$v_{result} = v_{plane} - v_{wind}$$
$$623.4\ ^{km}/_{h} = 670\ ^{km}/_{h} - v_{wind}$$
$$v_{wind} = 46.6\ ^{km}/_{h}$$

7. The English Channel is 35 km wide at its narrowest point, which is where most swimmers attempt to cross north to south from England to France. The current across this portion of the English Channel runs at about 2 km/h east to west.

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a. If a swimmer has a relative velocity to the shore of 3 km/h north to south, how long will it take her to cross the 35 km distance?

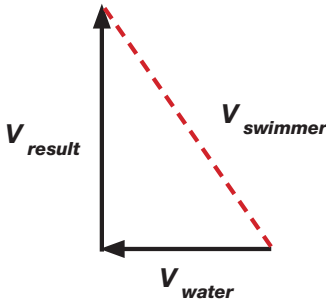
$$v_{result} = \frac{d}{t}$$

$$3\ ^{km}/_{h} = \frac{35\ km}{t}$$

$$t = \frac{35\ km}{3\ ^{km}/_{h}}$$

$$t = 11.67\ h$$

b. What must be her velocity relative to the water if she has a velocity of 3 km/h north to south relative to the shore?



$$v^2_{swimmer} = v^2_{water} + v^2_{result}$$

$$v^2_{swimmer} = (2\ ^{km}/_{h})^2 + (3\ ^{km}/_{h})^2$$

$$v^2_{swimmer} = 13\ ^{km^2}/_{h^2}$$

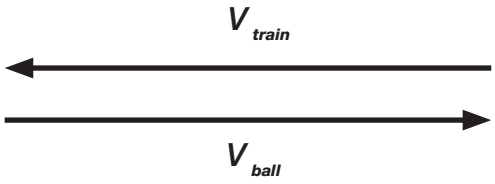
$$v_{swimmer} = 3.61\ ^{km}/_{h}$$

8. A train rolls at a constant speed of 10 m/s across a horizontal track. A child standing on the flatbed of the train throws a ball so that it appears to move straight up to an observer standing next to the track.

a. What is the horizontal speed of the ball relative to the observer?

If the ball appears to go straight up, its relative velocity to the observer is 0 m/s.

b. What is the horizontal speed of the ball relative to the train?

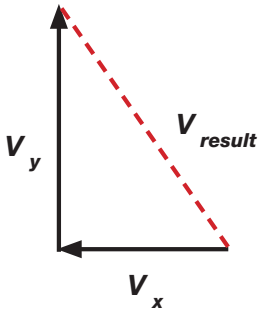


$$v_{result} = v_{train} - v_{ball}$$

$$0\ ^{m}/_{s} = 10\ ^{m}/_{s} - v_{ball}$$

$$v_{ball} = 10\ ^{m}/_{s}$$

c. If the ball is also thrown upward with a speed of 20 m/s, what is the overall initial speed of the ball relative to the train?



$$v^2_{result} = v^2_{x} + v^2_{y}$$

$$v^2_{result} = (10\ ^{m}/_{s})^2 + (20\ ^{m}/_{s})^2$$

$$v^2_{result} = 500\ ^{m^2}/_{s^2}$$

$$v_{result} = 22.36\ ^{m}/_{s}$$