COLLEGE PHYSICS

Chapter 3: Two-Dimensional Kinematics

Lesson 9

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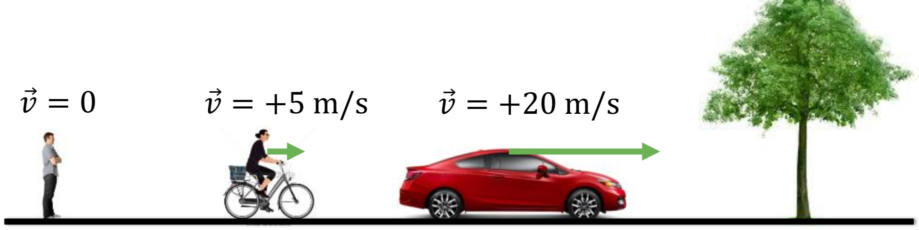
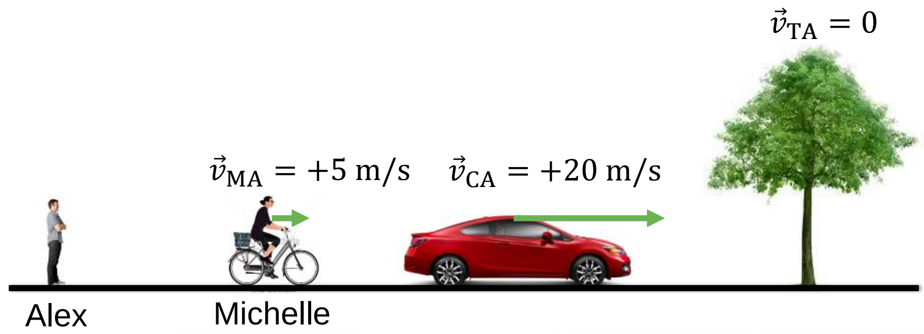
RELATIVE MOTION

- The figure below shows Alex, who is standing still.
- Michelle is on her bicycle, riding to the right at +5 m/s.
- There is a red car which is traveling to the right at +20 m/s.
- All of these velocities are relative to the **ground**, and the tree, and the rest of the earth.



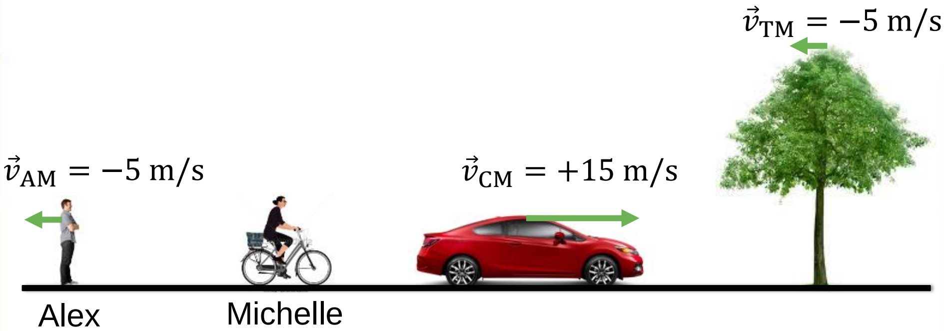
RELATIVE MOTION: THE WORLD ACCORDING TO ALEX

- From the point of view of Alex, Michelle and the car are moving, and we can measure their velocities relative to Alex.
- The subscript "MA" means "Michelle relative to Alex"
- The subscript "CA" means "Car relative to Alex"

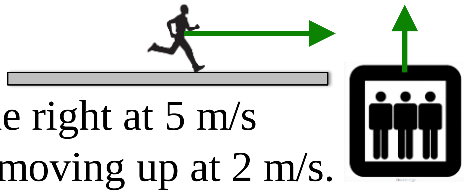


RELATIVE MOTION: THE WORLD ACCORDING TO MICHELLE

- From the point of view of Michelle, the car is moving slower, but still moving to the right.
- Relative to Michelle, Alex is moving to the **left**.
- The tree, and in fact the whole rest of the world is moving to the left at 5 m/s, relative to Michelle!
- All velocities are **relative** to some observer.



GIVE IT A TRY!



You are running toward the right at 5 m/s toward an elevator that is moving up at 2 m/s. Relative to you, the direction and magnitude of the elevator's velocity are

A. down and to the right, less than 2 m/s.
B. up and to the left, less than 2 m/s.
C. up and to the left, more than 2 m/s.
D. up and to the right, less than 2 m/s.
E. up and to the right, more than 2 m/s.

RELATIVE MOTION

$\vec{v}_{\mathrm{TG}} = +30\ \mathrm{m/s}$

$\vec{v}_{\mathrm{PT}} = +4\ \mathrm{m/s}$

$\vec{v}_{\mathrm{PG}} = +34\ \mathrm{m/s}$

$\vec{v}_{\mathrm{TG}}$ = velocity of the **T**rain relative to the **G**round

$\vec{v}_{\mathrm{PT}}$ = velocity of the **P**assenger relative to the **T**rain

$\vec{v}_{\mathrm{PG}}$ = velocity of the **P**assenger relative to the **G**round

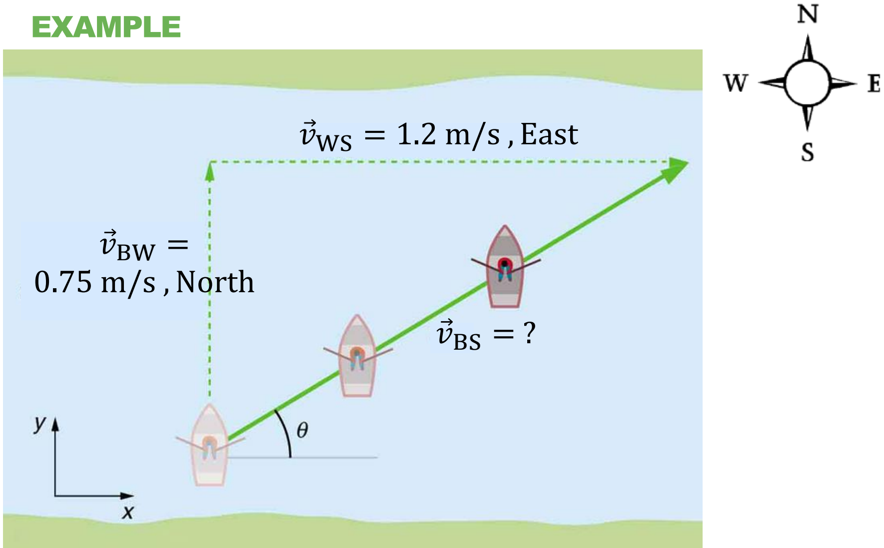
Note the "cancellation"

Also, note: $\vec{v}_{12} = -\vec{v}_{21}$

$$\vec{v}_{\mathrm{PG}} = \vec{v}_{\mathrm{PT}} + \vec{v}_{\mathrm{TG}}$$

Inner subscripts are the same

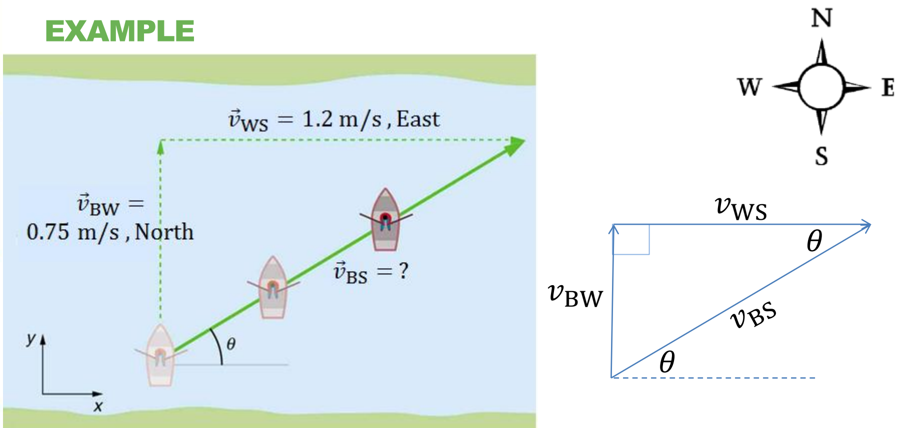
EXAMPLE



What is the velocity of the boat relative to the shore?

$$\vec{v}_{BS} = \vec{v}_{BW} + \vec{v}_{WS}$$

EXAMPLE



$$v_{BS} = \sqrt{{v_{BW}}^2 + {v_{WS}}^2} = 1.42 \text{ m/s}$$

$$\theta = \tan^{-1}\left(\frac{v_{BW}}{v_{WS}}\right) = 32.0°$$

$$\vec{v}_{BS} = 1.42 \text{ m/s}, 32.0° \text{ North of East}$$

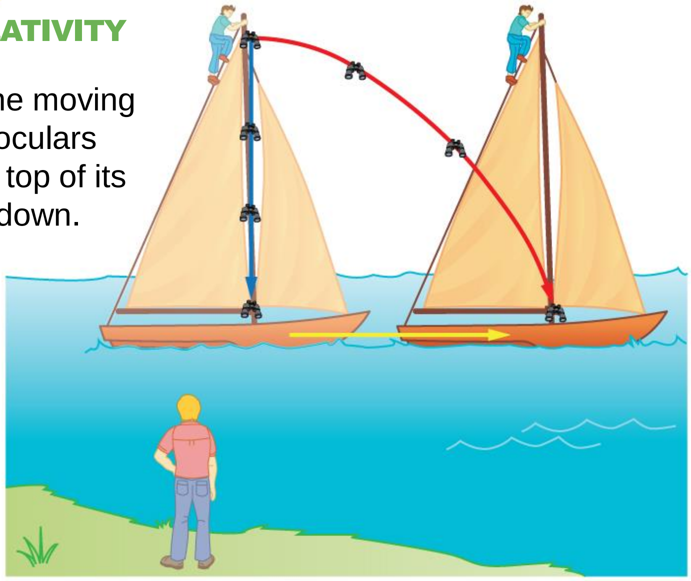
GIVE IT A TRY!

You are on an Eastbound subway train going at 20 m/s. You notice the Westbound train on the other track. Relative to the ground, that Westbound train has a speed of 20 m/s. What is the velocity of the Westbound train as measured by you?

A. 40 m/s, West
B. 20 m/s, West
C. zero
D. 20 m/s, East
E. 40 m/s, East

CLASSICAL RELATIVITY

An observer on the moving ship sees the binoculars dropped from the top of its mast fall straight down.



An observer on shore sees the binoculars take the curved path, moving forward with the ship.

Both observers see the binoculars strike the deck at the base of the mast.