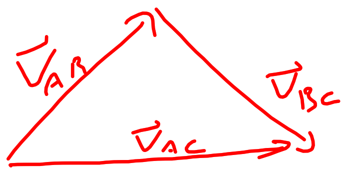


Relative Velocity

Relative Velocities - Linear Examples

$A - \cancel{B} + \cancel{B} - C = A - C$

$$\vec{v}_{A/C} = \vec{v}_{A/B} + \vec{v}_{B/C}$$

A with respect to C

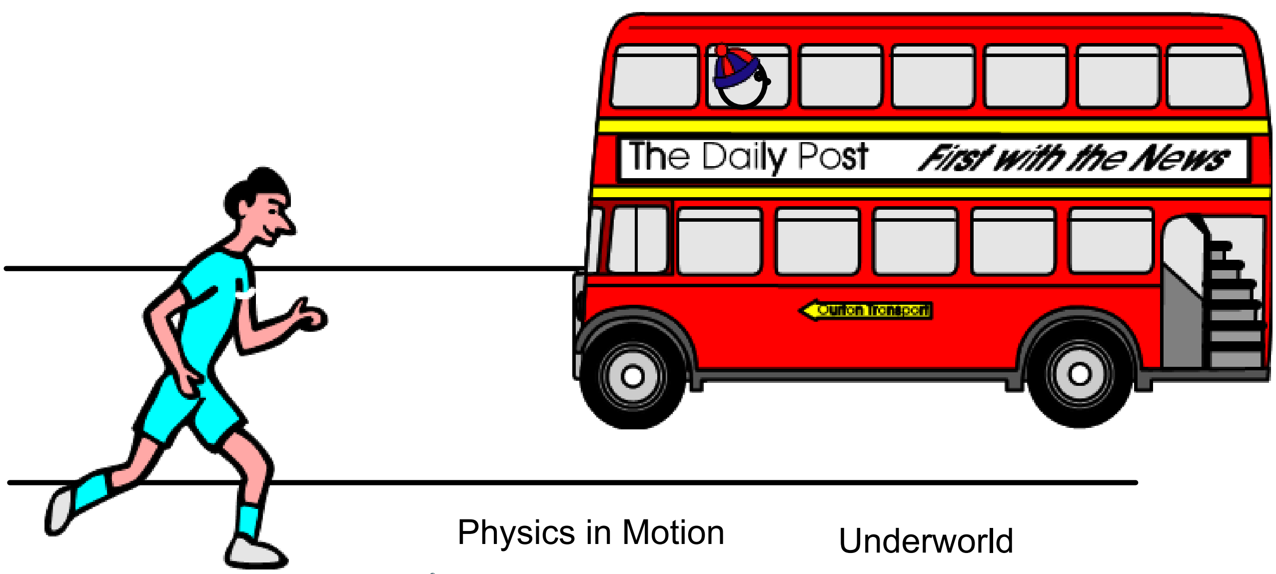
Bus is moving 28.8 km/h [S] relative to the ground. Matt, whose on the bus, walks 0.8 m/s [N] relative to the bus. Jordan jogs 1.5 m/s [N] relative to the ground. $28.8\ km/h = 8.0\ m/s$

a) Find $\vec{V}_{MG}$.

b) Find $\vec{V}_{JB}$.

.

c) Find $\vec{V}_{JM}$.



Physics in Motion Underworld

a) $\vec{v}_{M/B} = 0.8$ m/s [N]

$\vec{v}_{B/G} = -8.0$ m/s [N]

8.0 m/s [S]

$\vec{v}_{M/G} = \vec{v}_{M/\cancel{B}} + \vec{v}_{\cancel{B}/G}$

$= 0.8$ m/s + (-8.0 m/s)

= -7.2 m/s [N]

= 7.2 m/s [S]

b) $\vec{v}_{J/G} = 1.5$ m/s [N]

$\vec{v}_{B/G} = -8.0$ m/s [N]

$\vec{v}_{G/B} = 8.0$ m/s [N]

= -8.0 m/s [S]

$\vec{v}_{J/B} = \vec{v}_{J/\cancel{G}} + \vec{v}_{\cancel{G}/B}$

= 1.5 m/s + 8.0 m/s

= 9.5 m/s [N]

c) $\vec{v}_{M/B} = 0.8$ m/s [N]

$\vec{v}_{B/M} = -0.8$ m/s [N]

$\vec{v}_{J/B} = 9.5$ m/s [N]

$\vec{v}_{J/M} = \vec{v}_{J/\cancel{B}} + \vec{V}_{\cancel{B}/M}$

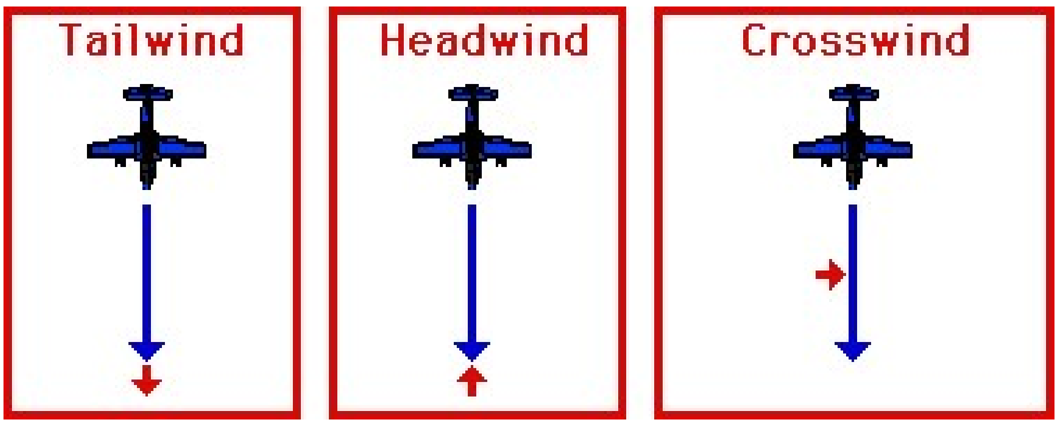
= 9.5 m/s + (- 0.8 m/s)

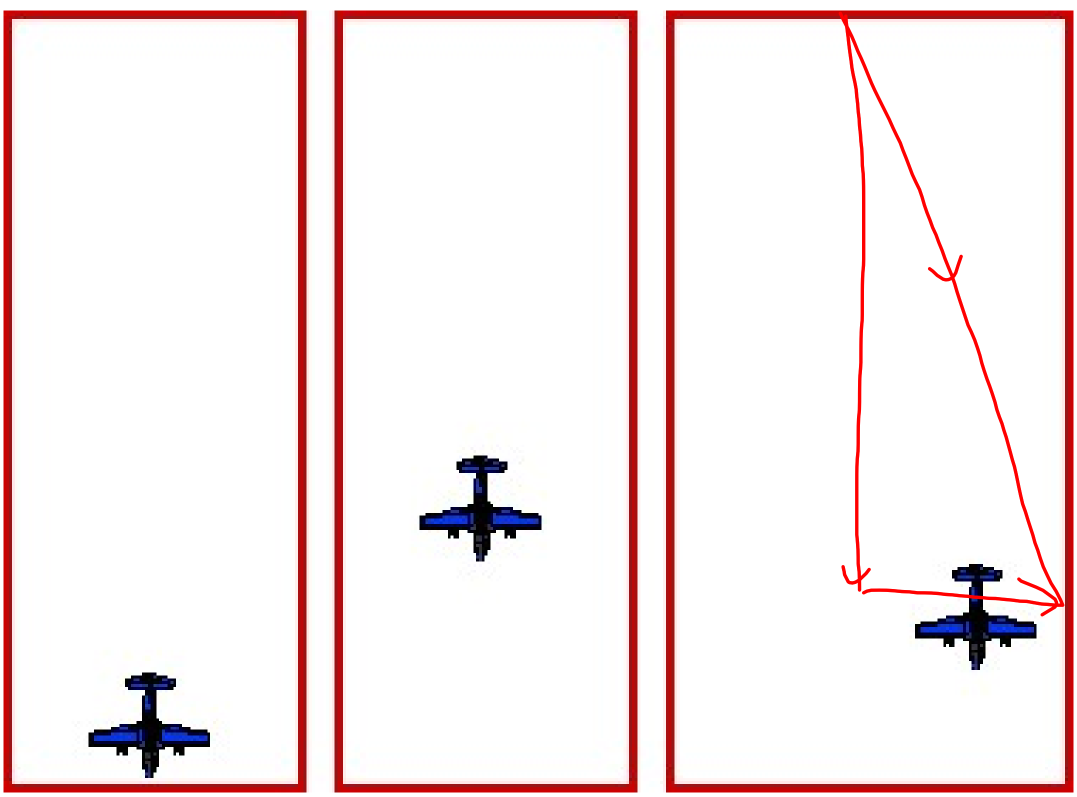
= 8.7 m/s [N]

OR

$\vec{v}_{J/M} = \vec{v}_{J/\cancel{G}} + \vec{v}_{\cancel{G}/\cancel{B}} + \vec{v}_{\cancel{B}/M}$

How would the wind (say 40 km/h relative to the ground) affect each of the resultant velocities?





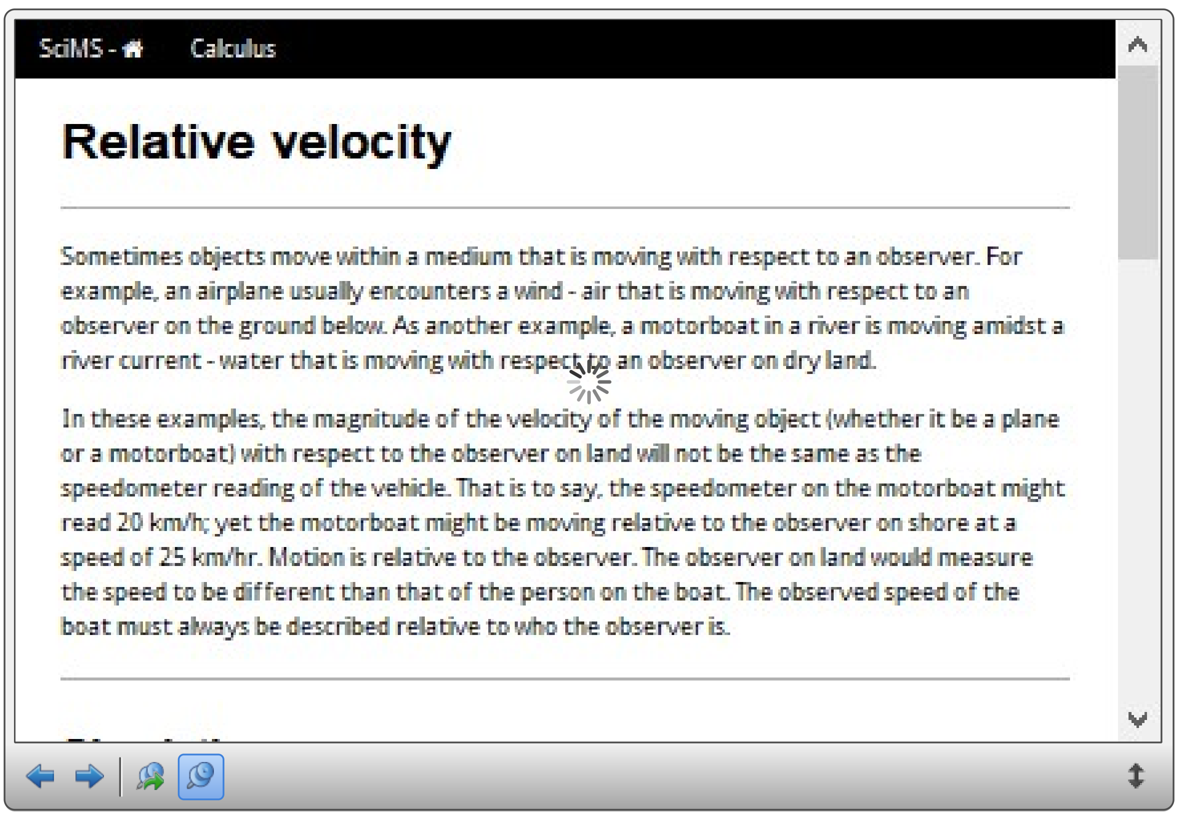
<u>Relative Velocities In Two Dimensions</u>

Perpendicular vectors act independently of each other.

The heading is the angle of the moving body - the direction the object is pointing.

The resultant velocity is typically the velocity of the object relative to the ground. An observer at rest on the ground would observe this motion.

Ex. boat in a river



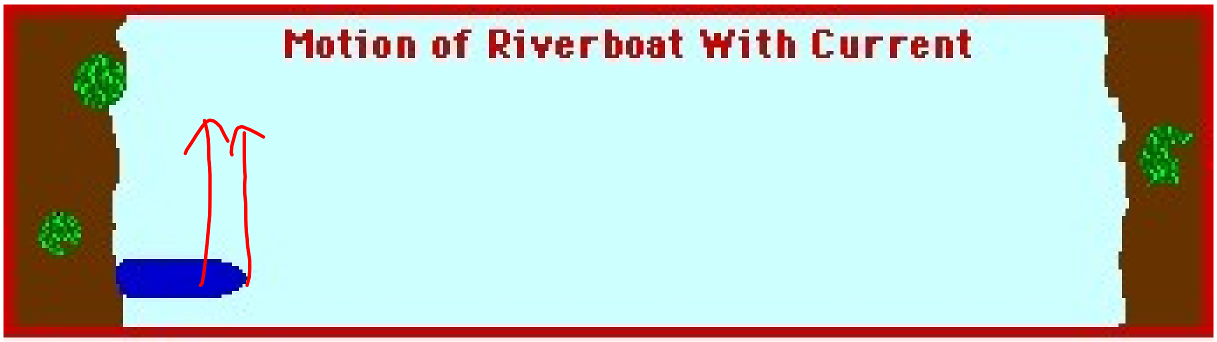
SciMS - Calculus

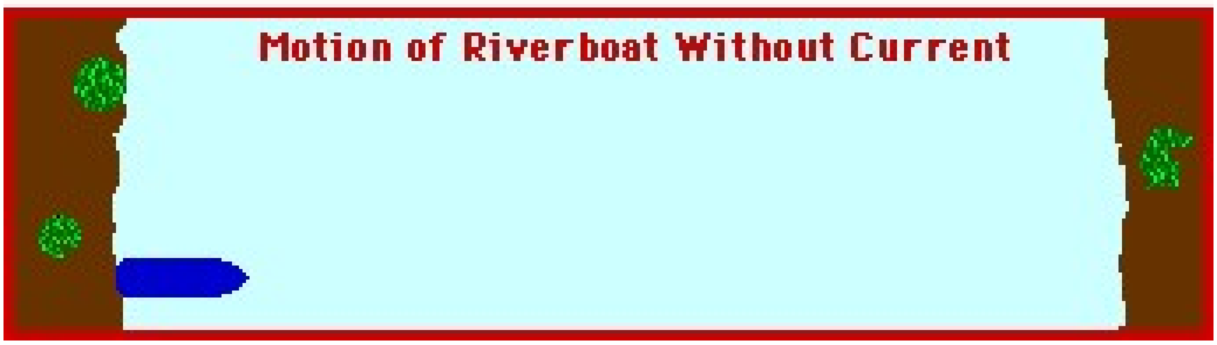
Relative velocity

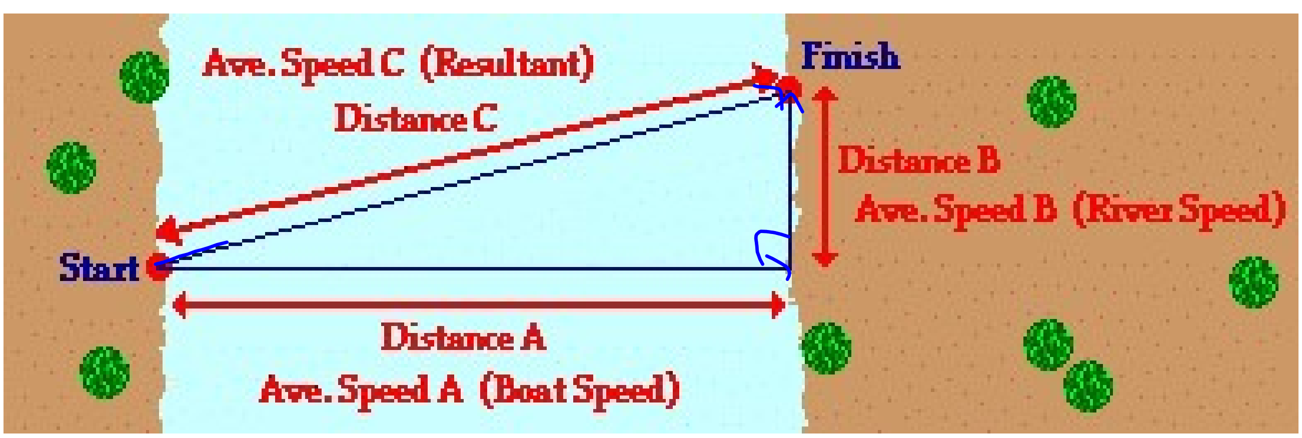
Sometimes objects move within a medium that is moving with respect to an observer. For example, an airplane usually encounters a wind - air that is moving with respect to an observer on the ground below. As another example, a motorboat in a river is moving amidst a river current - water that is moving with respect to an observer on dry land.

In these examples, the magnitude of the velocity of the moving object (whether it be a plane or a motorboat) with respect to the observer on land will not be the same as the speedometer reading of the vehicle. That is to say, the speedometer on the motorboat might read 20 km/h; yet the motorboat might be moving relative to the observer on shore at a speed of 25 km/hr. Motion is relative to the observer. The observer on land would measure the speed to be different than that of the person on the boat. The observed speed of the boat must always be described relative to who the observer is.

https://teaching.smp.uq.edu.au/scims/Calculus/Relative_velocity.html


Motion of Riverboat With Current


Motion of Riverboat Without Current


Ave. Speed C (Resultant)
Distance C
Finish
Distance B
Ave. Speed B (River Speed)
Start
Distance A
Ave. Speed A (Boat Speed)

Relative Velocity Examples

Ex. 1

A river flows from the west to the east. It is 750 m wide. Amanda and her friends are on the south shore of the river.

Amanda can swim 2.0 m/s relative to the water. Amanda's heading is always north. The river's current is flowing 3.0 m/s [E] relative to the ground.

a) What is Amanda's resultant velocity as witnessed by her friends on the shore?

b) How much time does it take Amanda to swim across the river (assuming velocities remain constant)?

c) How far downstream would Amanda land?

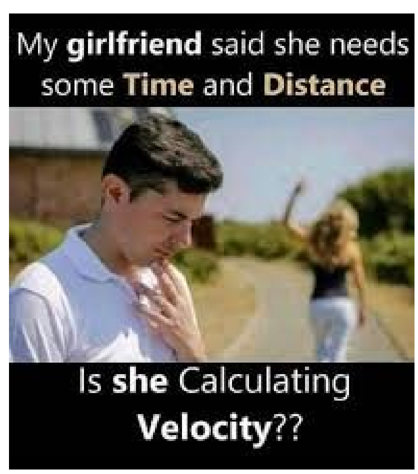
Ex. 2

Suppose the friends see Amanda's direction of travel is due north. Amanda is swimming 2.0 m/s relative to the water. The river's current is flowing 1.0 m/s [E] relative to the ground.

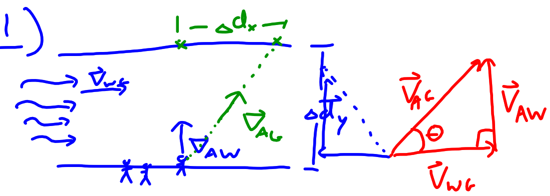
a) What is Amanda's heading (the angle at which she keeps her body) as crosses the river?

b) How much time does it take Amanda to swim across the river (assuming velocities remain constant)?

Do Practice Problems 22, 25, 27a on Page 110



Ex 1)



$\Delta\vec{d}_y = 750\ m\ [N]$

$|\vec{V}_{WG}| = V_{WG}$

$\vec{V}_{AW} = 2.0\ m/s\ [N]$

$\vec{V}_{WG} = 3.0\ m/s\ [E]$

$\vec{V}_{AG} = ?$

$$V_{AG}^2 = V_{AW}^2 + V_{WG}^2$$

$$V_{AG} = \sqrt{V_{AW}^2 + V_{WG}^2}$$

$$= \sqrt{(2.0\ m/s)^2 + (3.0\ m/s)^2} \qquad 13.0$$

$$= 3.60555\ m/s$$

$$\theta = \tan^{-1}\left(\frac{V_{AW}}{V_{WG}}\right) = \tan^{-1}\left(\frac{2.0\ \cancel{m/s}}{3.0\ \cancel{m/s}}\right) = 33.69° = 34°$$

$$\boxed{\vec{V}_{AG} = 3.61\ m/s\ [E\ 34°\ N]}$$

b) $\vec{V}_y = \vec{V}_{AW}$

$$\vec{V}_y = \frac{\Delta d_y}{\Delta t} \rightarrow \Delta t = \frac{\Delta d_y}{V_y}$$

$$\Delta t = \frac{750\ m}{2.0\ m/s} = 375\ s = \boxed{380\ s}$$

c) $\vec{V}_x = \vec{V}_{WG}$

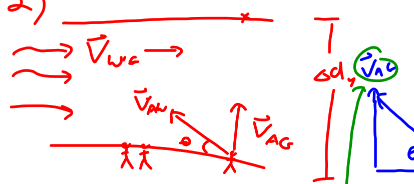
$$\Delta\vec{d}_x = \vec{V}_x \Delta t$$

$$= (3.0\ m/s)(375\ s) = 1125\ m$$

$$= \boxed{1100\ m}\ [E]$$

$$1.1 \times 10^3\ m\ [E]$$

#2)

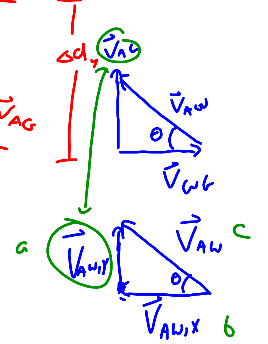


$\Delta d_y = 750\text{ m [N]}$

$\vec{V}_{WG} = 1.0\text{ m/s [E]}$

$V_{AW} = 2.0\text{ m/s}$

$\theta = ?$



$\cos(\theta) = \frac{A}{H} = \frac{V_{AW,x}}{V_{AW}}$

$V_{AW}\cos(\theta) = V_{AW,x}$

$V_{AW,x} = V_{WG}$

$V_{AW}\cos(\theta) = V_{WG}$

$\cos(\theta) = \frac{V_{WG}}{V_{AW}}$

$\theta = \cos^{-1}\left(\frac{V_{WG}}{V_{AW}}\right) = \cos^{-1}\left(\frac{1.0\text{ m/s}}{2.0\text{ m/s}}\right) = \boxed{60^\circ}$

$= \boxed{60^\circ \times 10^\circ}$

$\boxed{\theta = [W\ 60^\circ\ N]}$

b) $V_{AW}^2 = V_{AG}^2 + V_{WG}^2$

$V_{AW,y}^2 = V_{AG}^2 = V_{AW}^2 - V_{WG}^2 = V_{AW}^2 - V_{AW,x}^2$

$V_{AG} = \sqrt{V_{AW}^2 - V_{WG}^2}$

$= \sqrt{(2.0\text{ m/s})^2 - (1.0\text{ m/s})^2}$ 3.0

$= 1.7321\text{ m/s} \approx 1.7\text{ m/s} = \sqrt{3}\text{ m/s}$

$\Delta \vec{d}_y = \vec{V}_{AW,y}\,\Delta t \rightarrow \Delta t = \frac{\Delta d_y}{V_{AG}}$

$\Delta t = \frac{750\text{ m}}{1.7321\text{ m/s}} = 433.0\text{ s}$

$= \boxed{430\text{ s}}$