Name: _____

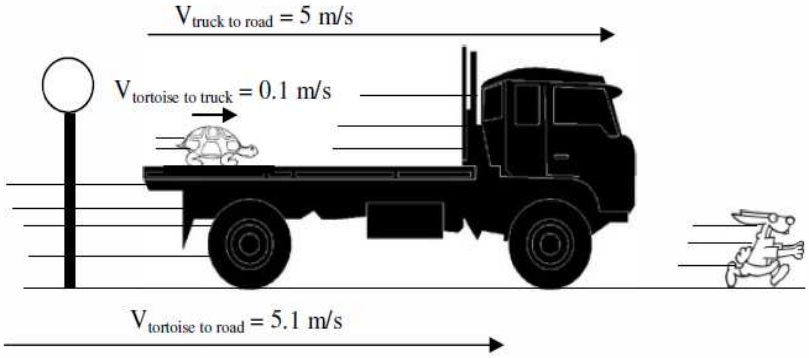
Period: _____

Relative Motion

Relative motion describes an object's motion relative (in relation) to different frames of reference.

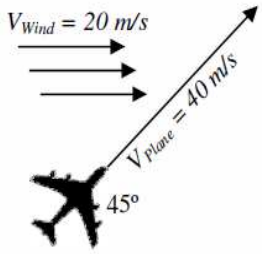
In the picture at the right the tortoise has a speed of 0.1 m/s relative to the truck, but has a speed of 5.1 m/s relative to the road.

In describing relative motion you must always give your frame of reference (the truck or the road).



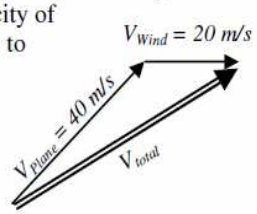
Vectors Still Add

Relative motion can be solved graphically or mathematically, just like all other vectors.



A plane flying has a velocity of 40 m/s, relative to the ground, experiences a west wind that is moving 20 m/s, relative to the ground. What is the velocity of the plane relative to the ground?

Graphically:



Mathematical Solution:

$Vx_{wind} = 20$

$Vx_{plane} = 40(\cos 45°) = 28.3$

$Vx_{total} = 20 + 28.3 = \mathbf{48.3 m/s}$

$Vy_{wind} = 0$ (*all horizontal*)

$Vy_{plane} = 40(\sin 45°) = 28.3$

$Vy_{total} = 0 + 28.3 = \mathbf{28.3 m/s}$

$V_{total} = \sqrt{48.3^2 + 28.3^2}$

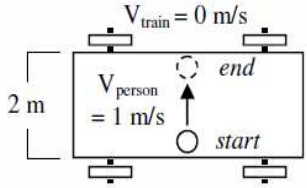
$V_{total} = 56$ m/s

$\theta = \tan^{-1}\left(\frac{28.3}{48.3}\right)$

$\theta = 30.4°$

See notes: "Adding Vectors"

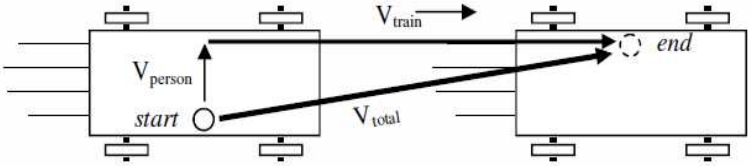
X and Y are Independent



Imagine a person walking 1m/s across a 2 m wide railroad car. If the car is at rest the person will take 2 seconds to cross.

To calculate V_{total}, use Pythagorean theorem:

$$V_{total}^2 = V_{person}^2 + V_{train}^2$$



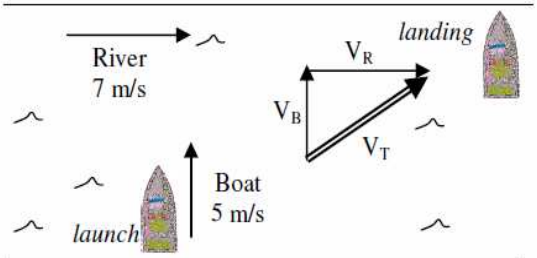
If the railcar is moving, the person still takes 2 seconds to cross the car. The velocity of the railcar is irrelevant because the velocity of the car is in the x-direction and the person is moving in the y-direction.

The x and y directions are independent of each other!

Not all motion is possible

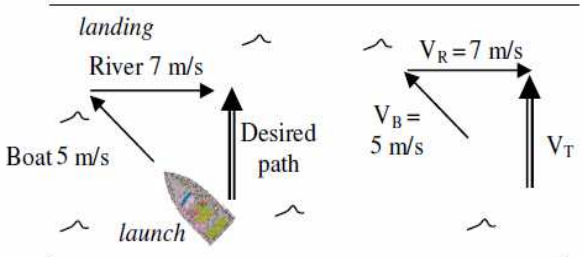
Remember that the resultant is drawn from the start of the first vector to the end of the last vector.

In the example below, a boat encounters a strong current in a river. If the boat captain aims straight across the river, the river will push the boat downstream.



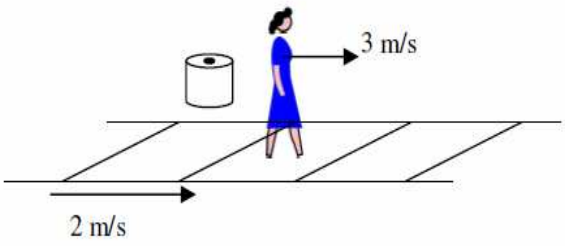
The total velocity of the boat is found by adding the vectors, which here requires only Pythagorean theorem, because these vectors are already horizontal and vertical.

But what if the captain wishes to land at a point straight across the river? The boat will have to be aimed up stream, but at what angle?



A vector triangle shows that this is not possible because the hypotenuse is smaller than one of the sides. The boat is not able to go straight across.

1. An moving walkway at the airport has a velocity of 2 m/s to the right. A person walks at a steady pace of 3 m/s.



   A. If the person is walking to the right, what is their velocity relative to the walkway?

   B. What is their velocity relative to the ground?

   C. How long would it take them to travel to the food court, 100 m away?

   D. How long would it take them to walk back if they have to walk on the same walkway?

   E. How long would it take them to walk to the food court and back without using the walkway?

2. A toy plane's is flying 55° going 8 m/s. If the wind is pushing with a velocity of 3 m/s at 30°, find the total velocity and direction of plane.

3. A boat is traveling 6 m/s at an angle of -30°. The water has a current flowing 3 m/s directly south. Find the boat's total velocity and direction.

4. A person can swim 4 m/s. The river has a current flowing 6 m/s directly east.

   A. What will be the direction and velocity of the person if they aim directly across the river (north)?

   B. If the person swims at constant speed, how long does it take them to swim across the 40 m wide river?

   C. How far downstream will the person drift?

   D. At what direction will the person have to swim to reach a point directly across the river?

   E. If the river's current increases (is faster), will the person take more or less time to cross the river?